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GLOBAL FORECAST MODEL TRIALS OF REVISED "FROZEN" PHYSICS

-second and third parallel suite trials

by
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1 Introduction

This note describes the results of tests with the global forecast model of the revised "frozen" physics package. The package as used in the first "frozen" climate model version was revised, as described in FR Technical Report no 75, to retain the ECMWF-like transmissivity formulation and the 1A cloud scheme, both of which are currently used operationally. The first parallel suite trial showed the new cloud scheme 1B to lead to unrealistic reduction in cloud amounts and to have some deficiences in formulation (see FR working paper no 152). A second parallel suite trial with the revised package was carried out from 09/08/93 to 31/08/03. After completion an error was found in the specification of the rates of evaporation of precipitation and so a third parallel trial was performed between 03/09/93 and 28/09/93 with this corrrected. This note documents the objective and subjective assessment of these trials.

In brief, the main conclusions of this work are:

there is generally a neutral impact on the objective scores;
showers are generally better predicted over land;
there is a tendency for a slight deepening of depressions which was favoured in the subjective assessment;
wind strengths were slightly increased and rms vector wind errors were generally slightly better;
the Hadley circulation is improved;
the package makes the global forecast model more consistent with the climate, mesoscale and limited area versions of the unifed model, all of which have already implemented the whole or substantial parts of the package.

The layout of the note is : - description of the package, section2; the objective assessment of the second parallel trial, section 3; the objective assessment of the third parallel trial, section 4; the subjective assessment of the third trial. Sections 3,4,5 have their own summaries of conclusions included.

2 Revised "Frozen" physics package

The differences from the current operational physics are as follows:

short wave radiation:

layer clouds in all layers replaced by 3 cloud types only, determined by maximum cloud amount in specified range of model layers (figure 2.1) with cloud water paths summed over same range used to parametrize optical properties;

longwave radiation:

random overlap of layer clouds replaced by maximal overlap of contiguous cloud layers and random overlap on non-contiguous groups of clouds; the climate version uses the standard treatment of transmissivities whereas the operational (and parallel

suite package) uses the ECMWF-like revised transmissivities;

boundary layer:

inclusion of rapidly mixing code which mixes heat and moisture over the full depth of an unstable boundary layer treated as a single bulk layer before locally mixing between separate model layers;

cloud:

as operational, 1A scheme. However ,the relative humidity thresholds have been changed in the lowest three model layers from 0.925 to 0.95,0.9,0.85 respectively. (Above these lowest layers the threshold remains unchanged at 0.85);

convection:

the downdraughts formed by evaporation of precipitation and now included. The rates of evaporation have also ben revised based on observations that evaporation from snow is generally more rapid than that from rain;

large-scale precipitation:

the evaporation has been revised as for convection. The threshold for precipitation formation has been reduced from 8 $x10^{-4}$ kg/kg to 2 x 10^{-4} kg/kg over sea, with the land retaining the higher value. Reducing the threshold leads to reduction in cloud particularly low cloud over summer oceans. The retention of a higher value over land reflects the larger number of CCN over land , and hence cloud water may be expected to reach larger values before precipitation commences. The treatment of ice precipiation has been made properly flux divergent (see UM Documentation paper 26) with separate depletion of water and ice fractions.

For the third trial:

corrected rates of evaporation of precipiation

3 Second parallel suite trial - objective assessment

The parallel trial ran from 09/08/93 to 31/08/93 with forecasts made from 12Z data to T+72. Forecasts, every 24h, and analyses were verified against observations and meaned over the period. The variables verified were:

PMSL, T1.5m,	
temperatures	levels 850,700,500,300,250,200,100,50 hPa
heights	levels 850,700,500,300,250,200,100,50 hPa
winds	levels 850,700,400,500,300,250,200,100 hPa
relative humidity	levels 850,700,500 hPa

The results were obtained for the standard verification areas:

area 2, N Atlantic and western Europe
200 Northern hemisphere from 30N
300 Tropics, 30N-30S
400 Southern hemisphere from 30S

Forecasts from operational and parallel suites were also verified against their own analyses. The same parameters were verified as for the verification against observations with the addition of relative humidity at 950hPa, and for the same areas. A selection from the various results to illustrate the general impact of the trial package is given below.

Temperatures

There is a small improvement at 500 hPa and below in the bias at T+72 , outside the tropics when compared to observations (Figs 3.01,3.02), and analyses (Figs 3.03,3.04). There is also an improvement in rms scores for these levels, particularly at 700hPa (Tables 3.1,3.2). In the tropics the bias is improved at 500 hPa but is worse at 700 and 850, due to the increased cooling from the evaporation of convective precipitation with the introduction of downdraughts. All the changes are of order 0.3 K or less. Similar , but smaller, changes are found for earlier forecast times. Many of the differences in rms are of order 1% or less for all levels and forecast times (see Tables 3.1, 3.2), except for the tropics where there are several changes $\sim 5\%$.

Heights

There are small improvements to the height biases outside the tropics, with generally comparable rms errors, eg for T+72 against observations (Figs 3.05, 3.06) and against analyses (Figs 3.07, 3.08). Area 2 has the largest improvements, when verified against observations, of order 3m for the bias and 2m for the rms ($\sim 3\%$) at 250 and 200hPa. For the tropics the height biases at 850 and 700 hPa are slightly worse and rms worse at these levels and 500 hPa (see Tables 3.3, 3.4) but scores are the same or slightly improved over operational at other levels. Looking at the percentage changes for all levels and forecast times, (Tables 3.3, 3.4), it is again apparent that the impact is generally very small with most differences of $\sim 1\%$ or less. The largest improvements are $\sim 3\%$ for area 2 and at upper tropical levels with the worst degradation in performance at 850 and 700 hPa in the tropics where the largest increase is $\sim 9\%$. Verification against analyses shows the southern hemisphere to be generally improved.

Winds

The trial shows a small reduction in the under-forecast mean strength, at nearly all levels for area 2 and the northern hemisphere (Figs 3.09,3.11), with the largest changes around 0.2 knots at T+48. (NB the 850 hPa analysis bias, Fig 3.13, is worse than the forecast bias, which gives the apparent positive bias when verified against analyses.) Rms vector wind errors are very similar between trial and operational with some indication of a general small improvement ($\sim$ 1 to 2%) for area 2 and the southern hemisphere (Tables 3.5, 3.6). In the southern hemisphere the impact is again mostly beneficial in increasing the mean wind strength, but the tropical changes are a mixture with slightly worse rms scores at the lower atmospheric levels (Figs 3.10,3.12) . The worst increase in vector wind error is $\sim 4\%$ at 700 hPa in the tropics (Tables 3.5, 3.6).

Relative humidity

The moist bias is smaller for area 2 and the northern hemisphere (Fig 3.14, T+72) but is worse for the southern hemisphere (Fig 3.15), with similar improvements and degradation in rms respectively. The moistening at 850 hPa in the Tropics appears to be an improvement as does the relative drying at 500hPa, although the rms is slightly worse at 850 and 700 hPa (Fig 3.15, Tables 3.7,3.8). Verification against analyses (Table 3.8) contradicts somewhat the verification against observations (Table 3.7) by generally favouring the operational.

Mean sea level pressure

Outside the tropics the mean bias shows a small deepening tendency which is

generally worse except for the southern hemisphere (Figs 3.16,3.17). The rms are generally comparable for area 2 and the northern hemisphere. The tropical bias is slightly less negative and the rms is better at most forecast times (Fig 3.17).

Surface temperature

There is a worsening of the cold bias in area 2 and the northern hemisphere, but a reduction in the southern hemisphere (Figs 3.18, 3.19). Rms errors are better however by ~0.1-0.15 K in all areas except for the southern hemisphere.

Overall summary

Many of the differences between the trial and operational verification scores are very small and the overall impact is "generally neutral". A count of the rms scores which are better or equal to the operational for each variable verified and for each area (Table 3.9) shows the trial to be better in area 2 for all parameters, winds usually better in all regions, except the northern hemisphere and a mixed response for other parameters elsewhere.

4 Third parallel suite trial - objective assessment

The parallel trial ran from 03/09/93 to 28/09/93 with forecasts made from 12Z data to T+72. However due to an inconsistency in the use of AIREPS which meant that AMDARS were not included in the parallel suite between 7th and 9th September the period before 10th was disregarded for the objective assessment and mean charts. Forecasts, every 24h, and analyses were verified against observations and meaned over the period 10/9/93 to 28/10/93. The variables verified were the same as for the second trial.

Forecasts from operational and parallel suites were also verified against their own analyses as before. A selection from the various results to illustrate the general impact of the trial package is given below.

Temperatures

There are small improvements at 300, 500 hPa and below in the bias at T+72 , outside the tropics when compared to observations (Figs 4.01,4.02), and analyses (Figs 4.03,4.04). The rms scores for these levels are also improved for areas 2 and the southern hemisphere in particular (Tables 4.1,4.2) ; however the rms is generally slightly worse for the northern hemisphere. In the tropics the bias is improved at 500 hPa but is worse at 700 and 850, due to the increased cooling from the evaporation of convective precipitation with the introduction of downdraughts. Again, all the changes are of order 0.3 K or less, considering all areas. Similarly, the differences in rms are mainly of order 1% or less for all levels and forecast times (see Tables 4.1, 4.2), except for the tropics where the differences in verification against analyses are more marked. The magnitude and character of these changes are very similar to those found for the second trial and so the impact of the correction to the evaporation rates of precipitation is minimal.

Heights

There are small improvements to the height biases (~1 or 2m) outside the tropics, with generally comparable rms errors, eg for T+72 against observations (Figs 4.05, 4.06) and against analyses (Figs 4.07, 4.08). The largest improvements are again for area 2 at 250 and 200 hPa, when verified against observations, and are of order 3m for the bias and 2m for the rms (~3%). The southern hemisphere improvement is most evident for verfication

against analyses and rms is ~2% better for most levels. For the tropics the height bias and rms at 700 hPa are only slightly worse with generallly better figures for the trial at levels up to 250 hPa (see Tables 4.3, 4.4). In this region the third trial is generally better than the second and so the correction to the evaporation of precipitation may be more effective here. Looking at the percentage changes for all levels and forecast times, Tables 4.3, 4.4, it is again apparent that the impact is generally very small with most differences of ~1% or less. The largest improvements are ~3% for area 2 at upper tropical levels with the worst degradation in performance at 700 hPa in the tropics at T+24 (~5%) , against analyses; however this is rather anomalous since figures for other times at this level show only a slight worsening of 1% or less. For height the figures for the third trial are better than or equal to the second trial. Overall the impact of the "frozen" physics is again mostly very small and neutral with some small beneficial improvements.

Winds

The trial has a small reduction in the under-forecast mean strength, at nearly all levels for area 2 and the northern hemisphere (Figs 4.09,4.11), with the largest changes around 0.4 knots at T+48. (NB the 850 hPa analysis bias is worse than the forecast bias, which gives the apparent positive bias when verified against analyses.) In the southern hemisphere the impact is again mostly beneficial, increasing the mean wind strength (Fig 4.10) when compared to the (few) observations but suggests worsening already overstrong winds when compared to analyses (Fig 4.12). In contrast to the second trial, the tropical rms vector wind errors are mostly reduced, by ~1 to 2% and the large degradation previously found at 700 hPa is no longer present. Rms vector wind errors are mostly very similar for the trial and operational . In area 2 there is a general small improvement (~ 1 to 2%) and for the southern hemisphere (Tables 4.5, 4.6) ; northern hemisphere figures are rather mixed but the changes are mostly < ~1%. The best improvements are seen in the tropics (Tables 4.5,4.6)

Relative humidity

The signal is somewhat confused for relative humidity since rather different responses are obtained for verification against observations and against analyses. Against observations, the moist bias is smaller, below 500 hPa, for area 2 and the northern hemisphere (Fig 4.13, T+72) but is worse for the southern hemisphere (Fig 4.14), with the rms improved or, equal to operational, respectively. The moistening at 850 and 700 hPa in the Tropics appear to be an improvement with the relative drying at 500hPa verifying slightly worse, although the rms is slightly better for all three levels (Fig 4.14, Table 4.7) Verification against analyses (Fig 4.15, 4.16,Table 4.8) contradicts somewhat the verification against observations with generally worse rms for the trial and so favouring the operational. For areas 2 and northern hemisphere, the bias at 850 and 900 hPa now shows a moistening compared to the operational whereas there was a drying at 850 hPa for verification against observations.

Mean sea level pressure

Outside the tropics the mean bias shows a small deepening tendency which is generally worse except for the southern hemisphere (Figs 4.17,4.18). The rms are generally comparable for all the extratropical areas. The tropical bias is slightly less negative and the rms is better at most forecast times (Fig 4.18).

Surface temperature

The cold bias is improved for area 2, the tropics and the southern hemisphere at later

forecast times but the northern hemisphere is generally worse. (figs 4.19,4.20). Rms errors are better however by ~0.1-0.15 K in all areas including the northern hemisphere.

Overall summary

As with the second trial many of the differences between the trial and operational verification scores are very small and the overall impact is "generally neutral". A count of the rms scores which are better or equal to the operational for each variable verified and for each area (Table 4.9) shows the trial to be better or comparable in area 2 for all parameters, except relative humidity against analyses; winds usually better in all regions, (except the northern hemisphere against analyses) . The southern hemisphere is generally improved and there is a mixed response for other parameters elsewhere. There is some beneficial impact on wind strengths as shown by the small reduction in negative wind speed bias.

5.SUBJECTIVE ASSESSMENT OF THE THIRD PARALLEL SUITE TRIAL OF THE "FROZEN PHYSICS PACKAGE"

Trial period 03/09/93 - 28/09/93

a) **Northern Hemisphere (North of 30N)**

Changes in the forecast mean sea level pressure and upper air fields were small in the Northern Hemisphere up to T+72 with only slight changes of evolution. Subjective assessment of these differences at T+72 was evenly balanced between the trial and operational versions.

Trial depressions tended to be slightly deeper at T+72, mostly by 1 to 4mb. If we consider just the 18 trial depressions which differed from the rival operational depressions by 4mb or more at T+72, then 15 were deeper, 9 correctly so. The subjective impression of slightly deeper lows is confirmed by the mean differences between trial and operational depressions listed in Table 5.1. below.

The maximum difference (12mb) between trial and operational depressions occurred in the T+72 forecast verifying at 12Z 27/9/93. The trial forecast, Figure 5.01(a), predicted a deep depression, 981mb, at 48N 150E, to the northeast of Japan. The operational forecast, Figure 5.01(b) was similar but the depression was less deep at 993mb. The verifying operational analysis, Figure 5.02, had a depression of 985mb in this position, favouring the trial forecast.

Trial jet maxima at 250mb tended to be slightly stronger at T+72, as shown in Table 5.1. Subjective assessment of the jet differences at T+72 favoured the trial version. We assessed 80 trial 250mb jet maxima at T+72 which differed by at least 5 knots from their operational counterparts, and 46 were closer to, 28 further from the verifying analyses.

	Depressions	250mb Jets
T+00	-0.0mb	0.0 knots
T+24	-0.2mb	0.1 knots
T+48	-0.2mb	0.1 knots
T+72	-0.6mb	1.2 knots

TABLE 5.1 Mean differences (trial - oper) between trial and operational depressions and jets forecast in the Northern Hemisphere during trial period 03/09/93 to 28/09/93

The main impact of the "Frozen Physics Package" in the Northern Hemisphere was seen in increased numbers of showers over both the land and sea. In general "frozen physics" showers were more frequent but lighter, showing a smoother working of the convection scheme compared to the intermittent working of the operational scheme. The trial forecasts predicted showers correctly overland on occasions when the operational forecast missed showers but sometimes the showers were too widespread.

At 12Z 8/9/93, the dominant feature in the Atlantic was a deep depression approaching Southwest England. The radar image for 12Z 08/09/93, Figure 5.03, shows a broad band of rain stretched over Northern England with showers to the south and over Wales. The significant weather chart for 18Z in Figure 5.03 shows the location of thunderstorms reported over the Midlands and North Wales during the afternoon. The T+48 forecasts of mean sea level pressure and rainfall from the trial and operational models are compared in Figures 5.04(a),(b) respectively. The forecast pressure patterns were almost identical but the trial forecast which predicted many more showers over England and Wales was better in this case.

The trial forecast, Figure 5.04(a), predicted showers from a trough over the west Mediterranean and Algeria and some light showers further south over the Sahara. In contrast, the operational forecast predicted only very isolated light showers. The meteosat infrared satellite imagery for 12Z 08/09/93, Figure 5.05, shows an area of cloud over North Africa and the west Mediterranean, with some whiter lumpy areas indicative of convective cells, justifying the trial forecast of showers. There is also an area of cloud further south over the Sahara with isolated small convective cells but it is doubtful that they could have given any isolated light showers at the surface.

Finally, the trial version predicted light showers to be more widespread over the Atlantic south of 40N and west of 30W. This was a regular feature of all the trial forecasts.

The average precipitation (convective and total) per grid point meaned over a period of 16 days from 10/09/93 - 25/09/93 for the Northern Hemisphere north of 30N and also for Area 2 is listed in Table 5.2.

For the whole area, the table shows that convective accumulations were higher in the trial forecasts at all times but with a compensating reduction in dynamic accumulations. For Area 2, the convective and total accumulations were slightly less in the trial version at T+00 and T+12 but slightly higher at all other times.

Northern Hemisphere

a) convective precipitation

	North of 30N		Area 2	
Time	trial	oper	trial	oper
T+00	0.165	0.138	0.445	0.458
T+12	0.514	0.419	1.399	1.427
T+24	0.938	0.767	2.472	2.376
T+36	1.384	1.111	3.469	3.304
T+48	1.829	1.459	4.504	4.238
T+72	2.725	2.157	6.505	6.070
b)total precipitation				
T+00	0.389	0.396	0.624	0.655
T+12	1.249	1.248	1.954	2.033
T+24	2.249	2.236	3.497	3.490
T+36	3.351	3.294	4.982	4.940
T+48	4.470	4.377	6.558	6.449
T+72	6.763	6.566	9.573	9.363

Table 5.2 Mean precipitation in mm/gridpoint over the period 10/09/93 - 25/09/93 at the time stated.

The "frozen physics" forecasts were slightly cloudier overall, but the difference was only 2-3%. The average amounts of low, medium and high clouds in the trial and operational forecasts at T+36 and T+72 from the parallel suite trial meaned over the period 03/09/93 to 28/09/93 are listed in Table 5.3 below.

a) Northern Hemisphere (north of 30N)

Time	Low cloud		Medium cloud		High cloud	
	trial	oper	trial	oper	trial	oper
T+36	31.8	32.1	22.4	20.6	28.2	26.1
T+72	32.7	31.8	24.7	23.2	29.1	26.8

b) Northern Hemisphere - Area 2

Time	Low cloud		Medium cloud		High cloud	
	trial	oper	trial	oper	trial	oper
T+36	32.0	31.4	24.8	22.8	30.1	27.6
T+72	34.1	33.0	27.1	25.7	31.3	29.0

TABLE 5.3. Mean percentage of low,medium and high cloud in the Northern Hemisphere forecasts during period 03/09/93 to 28/09/93

Some of the "frozen physics" changes, e.g. the rapidly mixing boundary layer scheme and the changes in critical relative humidity thresholds, are expected to have an impact on the distribution of cloud in the five lowest model layers. We were not able to assess the impact in the forecasts due to the lack of model level data in the operational printfile for comparison. By running a one timestep forecast from the parallel suite and operational analyses, we were able to compare cloud amounts in the five lowest model levels at T+00 and these figures are listed in Table 5.4 below. The table shows the expected impact; a small reduction of cloud in the two bottom levels with an increase in levels 3-5. The amount of cloud in level 1 was also affected by the different treatment of cloud ice. The level 1 cloud difference chart for the Northern hemisphere, Figure 5.06, shows an increase of cloud over frozen areas such as the North Pole, and parts of Greenland and Northern Canada.

Model level	N.Hem.(N of 30N)		N.Hem.(Area 2)	
	trial	oper	trial	oper
level 1	7.7	7.9	4.7	5.2
level 2	12.4	14.2	7.1	9.0
level 3	13.7	11.6	9.4	7.9
level 4	13.4	12.3	9.6	8.8
level 5	11.6	10.4	7.9	7.0

TABLE 5.4. Average percentage of layer cloud in model levels 1-5 in the Northern Hemisphere at T+00, meaned over the period DT12Z 10/9/93 to DT12Z 21/9/93.

Overall, the subjective asessment favoured the trial forecasts from the "frozen physics package" .

b. **Tropics (30N - 30S)**

Tropical depressions were deeper in the trial forecasts by about 4mb. Differences were noticed in the subtropical jets in the Southern Hemisphere between 25S and 30S, at T+48 and T+72. Small changes in evolution meant that the trial jets could be either weaker or stronger than the operational jets but there was an overall tendency for the trial jets to be weaker.

The assessment of these differences relied on the respective analyses plus a few observations. We assessed 54 trial 250mb jet maxima at T+72 in the southern Tropics which differed by at least 5 knots from their operational counterparts, and of these, 22 were closer to, 20 further from the verifying analyses.

In the subjective assessment, however,the most noticeable difference in the Tropics was the increase in the number of showers predicted both over the sea in the ITCZ and over land. There was no overall increase in total rainfall in the Tropics, hence although trial showers were more widespread, they were also lighter. There was also a transfer of rainfall from sea to land.

The T+24 rainfall forecasts for Africa and South America verifying at 12Z 26/09/93 from the trial and operational models are compared in Figures 5.07 (a) and (b) respectively. The main impact of the "frozen physics package" over Africa can be seen in the increased number of moderate/heavy showers predicted over Central Africa between at 10N and 10S and also in the extra light showers predicted between 10S and 20S.

Rainfall over Africa is difficult to verify due to lack of observations and depends on satellite imagery. The meteosat infrared satellite imagery over Africa for 12Z 26/09/93 is shown in Figure 5.08. The heaviest rain area over Central Africa is portrayed in both forecasts but it is difficult to judge which is better; i.e. the operational forecast misses more but the trial forecast showers may be too widespread. The satellite picture shows an area of cloud between 10S and 25S, which roughly corresponds to the light shower area predicted by the trial forecast. Over the oceans, the trial forecast many more light showers which were possibly too widespread.

Figures 5.09 (a) and (b) compare the trial and operational T+24 rainfall forecasts for the Indian Ocean, the South Pacific, Asia and Australia, verifying at 12z 21/09/93. Characteristic differences between the two versions are shown by the increased number of showers predicted by the trial version over the sea in the ITCZ. In the trial version, showers are more widespread but individual showers are lighter. The NOAA-11 infrared satellite imagery for 12Z 21/09/93 in Figure 5.10 shows a large area of cloud over India and the Bay of Bengal with embedded convective cells. The main storm area at 80E is better predicted by the increased showers in the trial forecast.

The mean convective and dynamic rainfall accumulations for the Tropics are shown in the Table 5.5. This table shows that the

overall rainfall amount in the tropics changed very little. Up to T+24, the trial version predicted slightly less; after T+24, the trial version predicted slightly more. Since the trial verion predicts increased showers, this table confirms that the trial showers are not so heavy.

Time	convective trial	convective oper	total trial	total oper
T+00	0.718	0.777	0.769	0.829
T+12	2.274	2.341	2.429	2.496
T+24	3.833	3.854	4.100	4.123
T+36	5.391	5.351	5.758	5.725
T+48	6.931	6.863	7.412	7.352
T+72	10.103	9.910	10.819	10.629

Table 5.5 Average precipitation in mm/gridpoint meaned over the period 10/09/93 - 25/09/93 for the period stated.

c. Southern Hemisphere (south of 30S)

Although there were more differences between trial and operational forecasts in the Southern Hemisphere, changes in evolution were small up to T+72 and the subjective assessment of the differences worked out evenly.

Trial depressions tended to be slightly deeper. When we assessed the 50 trial depressions which differed from their operational counterparts by at least 4mb at T+48 and T+72, then 40 were deeper by 4-8mb, 20 correctly. The overall deepening is reflected in the mean differences between trial and operational depressions in Table 5.3 below.

Unlike the first "frozen physics" trial, there was no clear bias between trial and operational jet maxima. We assessed 142 250mb jet maxima at T+48 and T+72 when there was a difference of more than 5 knots between trial and operational forecasts. Of these, 64 trial forecasts were closer to the analysis and 57 further from the analysis; 75 trial forecasts were stronger and 67 weaker. These results may suggest a "narrow win" for stronger trial jets but the differences were probably not significant bearing in mind the lack of supporting observations in the Southern Hemisphere. The mean differences between trial and operational depressions and jets are listed in Table 5.3 below.

	Depressions	250mb Jets
T+00	-0.3mb	0.1 knots
T+24	-0.4mb	0.1 knots
T+48	-0.9mb	0.1 knots
T+72	-1.0mb	0.3 knots

TABLE 5.6 Average differences (trial - oper) between trial and operational depressions and jets in the Southern Hemisphere meaned over the period 03/09/93-28/09/93

Case studies from the Southern Hemisphere during this trial were not very exciting as differences in evolution were small and difficult to verify. A "typical" example can be seen in Figure 5.11, which compares the trial and operational T+72 mean sea level pressure forecasts verifying at 12Z 23/9/93. The main difference between the forecasts lies in the region 40S-50S, 110W, where the trial version has predicted a low of 998mb and the operational version a low of 1005mb. Both versions analysed a low of 990mb at 50N 105W (Figure 5.12), resulting in a "win" for the trial forecast.

There was an overall small increase in layer cloud of 1-4% in the trial forecasts. The mean differences between trial and operational cloud amounts are listed in Table 5.7 below.

	Low cloud		Medium cloud		High cloud	
	trial	oper	trial	oper	trial	oper
T+36	44.1	40.4	32.3	30.0	28.8	27.5
T+72	43.9	39.6	34.0	31.9	30.5	28.8

TABLE 5.7 Mean percentages of Low, Medium and High cloud forecast in the Southern Hemisphere during the period 03/09/93 to 28/09/93

By running a one timestep forecast from the parallel suite and operational analyses, we were able to compare cloud amounts in the five lowest model levels at T+00 and these figures are listed in Table 5.8 below. The amount of cloud in level 1 was affected not only by the critical humidity threshold changes but also by the different treatment of cloud ice. Table 8 shows a large increase in the trial level 1 cloud of 7.2%. In fact the trial has more cloud at every level in the boundary layer.

Model level	Southern Hemisphere.(South of 30S)	
	trial	oper
level 1	15.6	8.4
level 2	21.7	18.7
level 3	27.2	23.6
level 4	21.6	17.2
level 5	19.2	16.4

TABLE 5.8. Average percentage of layer cloud in model levels 1-5 in the Southern Hemisphere at T+00, meaned over the period DT12Z 10/9/93 to DT12Z 21/9/93.

The level 1 cloud difference chart for the Southern Hemisphere, Figure 5.13, shows an increase of cloud over frozen areas such as Antartica.

The average precipitation (convective and total) per grid point meaned over a period of 16 days from 10/09/93 - 25/09/93 for the whole of the Southern Hemisphere south of 30S is listed in Table 5.9. Both convective and dynamic accumulations were higher in the trial forecasts at all times.

Southern Hemisphere

	convective		total	
Time	trial	oper	trial	oper
T+00	0.114	0.089	0.464	0.455
T+12	0.377	0.298	1.429	1.403
T+24	0.670	0.535	2.469	2.413
T+36	0.982	0.787	3.542	3.446
T+48	1.300	1.040	4.659	4.501
T+72	1.960	1.573	6.946	6.678

Table 5.9 Mean precipitation in mm/gridpoint over the period 10/09/93 - 25/09/93 at the time stated.

d. Zonal mean cross-sections and field charts

The zonal mean cross-sections and field charts described in this section were meaned over the forecasts run during the period 12Z 10/09/93 - 12Z 28/09/92 from the parallel suite trial. The first week was excluded in order to avoid the period 7th - 9th September when amdars were excluded from the parallel suite forecast.

(i) Zonal mean temperature cross sections (Figures 5.14 a and b)
These cross sections show temperature differences in degrees Celsius at 10 standard levels between 950mb and 50mb between the trial and operational forecasts (trial - oper) at T+36 and T+72 respectively.

The maximum impact can be seen in the Tropics. There is a small cooling of 0.2C - 0.3C just below the tropopause centred on 230mb, with a warming of 0.2C - 0.3C in the stratosphere at 150mb, thus effectively raising the tropopause slightly. In the northern Tropics, the main feature is the marked cooling at low levels, centred at 800mb, which increases during the forecast from 0.5C at T+36 to 0.7C at T+72. In the southern Tropics, there is a slight decrease in instability, with a cooling of 0.4C near the surface topped by a small warming of 0.3C at 650mb.

In the Northern Hemisphere autumn and Southern Hemisphere spring temperature changes were only slight.

(ii) Zonal mean wind cross sections (Figures 5.15 - 5.19)
(a) The cross sections shown in Figures 5.15 a and b respectively show the zonal mean "u-component" of the wind at 10 standard levels between 950mb and 50mb from the trial and operational T+72 forecasts. A comparison of the cross-sections show very little impact overall of the frozen physics package on the "u-component".

(b) The cross sections shown in Figures 5.16 and 5.17 show the zonal mean "v-components" of the wind at 10 standard levels between 950mb and 50mb from the trial and operational T+36 and T+72 forecasts. The meridional flow errors at T+72 for September 1993 are shown in the cross section in Figure 5.19a. Both the trial and operational forecasts show the systematic model errors in the Hadley Cell, with a strengthening of the upper branch to ~3.5 m/s at T+36/72, compared to the analysed value of ~2.0 m/s (Figure 5.18). Secondary flows at around 700mb and 450mb are also present in both trial and operational forecasts but there is no

evidence for these in the analysis. However from the difference chart for T+72, Figure 5.19b, it is apparent that the trial has significantly weakened the low level southerly branch of the main cell and also weakened the upper branch and secondary circulations. These are all improvements and are in the correct sense to partially correct the typical systematic errors for T+72 for September, Figure 5.19a.

(iii) Zonal mean relative humidity cross sections (Figure 5.20)

The cross sections show differences in relative humidities at ten standard levels between 950mb and 50mb between trial and operational forecasts at T+36 and T+72. The only significant impact is in the tropics. In the northern Tropics, there is an increase of humidity up through most of the troposphere, with a peak of 8% at 700mb. In the southern Tropics, a slight increase in humidity at low levels is accompanied by a drying in the upper troposphere, with a maximum of 7% at 600mb.

(iv) Mean sea level pressure at T+72 (Figure 5.21 and 5.22)

The trial and operational T+72 zonally averaged mslp charts are compared in Figure 5.21 (a) and (b) respectively. The main features are almost identical and the difference chart, Figure 5.22, shows only small differences mainly in the Southern Hemisphere.

(v) Winds at 850mb and 250mb.(Figures 5.23-5.25)

A comparison of mean 850mb winds from the trial and operational forecasts at T+72 (Figures 5.23 a and b respectively) show very little impact in the Northern and Southern Hemisphere outside of the tropics. The difference chart (trial - operational), Figure 5.25a, shows that the main impact has been in the flow south of India, which is slightly more cyclonic in the trial forecast.

The mean jets at 250mb from the trial and operational forecasts are compared in Figures 5.24 a and b respectively. The main polar and subtropical jets are very similar and the difference chart in Figure 5.25b show that the main impact has been in the lighter winds in the tropics.

(e) CONCLUSIONS

(i) Northern Hemisphere.

The assessment of slight evolution changes in mean sea level pressure and upper air forecasts at T+72 marginally favoured the trial forecasts. Depressions tended to be slightly deeper and 250mb jets stronger. The main impact of the "frozen physics package" in the Northern Hemisphere was seen in the increase in the number of showers overland. This was mostly beneficial but the predicted showers could be too widespread at times. There was also an increase in the number of light showers over the sea south of 40N.

(ii) Tropics

The assessment of differences in trial and operational jets in the Southern Hemisphere tropics was evenly balanced between

trial and operational forecasts. There was a slight reduction in jet wind speeds in the Southern Tropics. The main impact of the "frozen physics package" in the Tropics was seen in the increase in number of showers in the ITCZ and overland. The trial forecast of showers overland was an improvement but areas of light showers over the seas were overdone. There was no increase in total rainfall.

(iii Southern Hemisphere.

The assessment of evolution changes in mean sea level pressure and upper air forecasts was evenly balanced between trial and operational forecasts. Depressions tended to be slightly deeper and there was a slight increase in low cloud and convective and dynamic rainfall. There was an increase in level 1 cloud over frozen surfaces in Antartica.

Figure captions

3.01 Mean bias and rms from verification against observations for temperature at T+72 plotted against pressure ; areas 2 and northern hemisphere; trial 2

3.02 Mean bias and rms from verification against observations for temperature at T+72 plotted against pressure ; tropics and southern hemisphere; trial 2

3.03 Mean bias and rms from verification against analyses for temperature at T+72 plotted against pressure ; areas 2 and northern hemisphere; trial 2

3.04 Mean bias and rms from verification against analyses for temperature at T+72 plotted against pressure ; tropics and southern hemisphere; trial 2

3.05 Mean bias and rms from verification against observations for height at T+72 plotted against pressure ; areas 2 and northern hemisphere; trial 2

3.06 Mean bias and rms from verification against observations for height at T+72 plotted against pressure ; tropics and southern hemisphere; trial 2

3.07 Mean bias and rms from verification against analyses for height at T+72 plotted against pressure ; areas 2 and northern hemisphere; trial 2

3.08 Mean bias and rms from verification against analyses for height at T+72 plotted against pressure ; tropics and southern hemisphere; trial 2

3.09 Mean bias and rms from verification against observations for winds at T+48 plotted against pressure ; areas 2 and northern hemisphere; trial 2

3.10 Mean bias and rms from verification against observations for winds at T+48 plotted against pressure ; tropics and southern hemisphere; trial 2

3.11 Mean bias and rms from verification against analyses for winds at T+48 plotted against pressure ; areas 2 and northern hemisphere; trial 2

3.12 Mean bias and rms from verification against analyses for winds at T+48 plotted against pressure ; tropics and southern hemisphere; trial 2

3.13 Mean bias and rms from verification against observations for winds at T+0 plotted against pressure ; areas 2 and northern hemisphere; trial 2

3.14 Mean bias and rms from verification against observations for relative humidity at T+72 plotted against pressure ; areas 2 and northern hemisphere; trial 2

3.15 Mean bias and rms from verification against observations for relative humidity at T+72 plotted against pressure ; tropics and southern hemisphere; trial 2

3.16 Mean bias and rms from verification against observations for surface pressure plotted against forecast period ; areas 2 and northern hemisphere; trial 2

3.17 Mean bias and rms from verification against observations for surface pressure plotted against forecast period ; tropics and southern hemisphere; trial 2

3.18 Mean bias and rms from verification against observations for surface temperature plotted against forecast period ; areas 2 and northern hemisphere; trial 2

3.19 Mean bias and rms from verification against observations for surface temperature plotted against forecast period ; tropics and southern hemisphere; trial 2

4.01 Mean bias and rms from verification against observations for temperature at T+72 plotted against pressure ; areas 2 and northern hemisphere; trial 3

4.02 Mean bias and rms from verification against observations for temperature at T+72 plotted against pressure ; tropics and southern hemisphere; trial 3

4.03 Mean bias and rms from verification against analyses for temperature at T+72 plotted against pressure ; areas 2 and northern hemisphere; trial 3

4.04 Mean bias and rms from verification against analyses for temperature at T+72 plotted against pressure ; tropics and southern hemisphere; trial 3

4.05 Mean bias and rms from verification against observations for height at T+72 plotted against pressure ; areas 2 and northern hemisphere; trial 3

4.06 Mean bias and rms from verification against observations for height at T+72 plotted against pressure ; tropics and southern hemisphere; trial 3

4.07 Mean bias and rms from verification against analyses for height at T+72 plotted against pressure ; areas 2 and northern hemisphere; trial 3

4.08 Mean bias and rms from verification against analyses for height at T+72 plotted against pressure ; tropics and southern hemisphere; trial 3

4.09 Mean bias and rms from verification against observations for winds at T+48 plotted against pressure ; areas 2 and northern hemisphere; trial 3

4.10 Mean bias and rms from verification against observations for winds at T+48 plotted against pressure ; tropics and southern hemisphere; trial 3

4.11 Mean bias and rms from verification against analyses for winds at T+48 plotted against pressure ; areas 2 and northern hemisphere; trial 3

4.12 Mean bias and rms from verification against analyses for winds at T+48 plotted against pressure ; tropics and southern hemisphere; trial 3

4.13 Mean bias and rms from verification against observations for relative humidity at T+72 plotted against pressure ; areas 2 and northern hemisphere; trial 3

4.14 Mean bias and rms from verification against observations for relative humidity at T+72 plotted against pressure ; tropics and southern hemisphere; trial 3

4.15 Mean bias and rms from verification against analyses for relative humidity at T+72 plotted against pressure ; areas 2 and northern hemisphere; trial 3

4.16 Mean bias and rms from verification against analyses for relative humidity at T+72 plotted against pressure ; tropics and southern hemisphere; trial 3

4.17 Mean bias and rms from verification against observations for surface pressure plotted against forecast period ; areas 2 and northern hemisphere; trial 3

4.18 Mean bias and rms from verification against observations for surface pressure plotted against forecast period ; tropics and southern hemisphere; trial 3

4.19 Mean bias and rms from verification against observations for surface temperature plotted against forecast period ; areas 2 and northern hemisphere; trial 3

4.20 Mean bias and rms from verification against observations for surface temperature plotted against forecast period ; tropics and southern hemisphere; trial 3

5.01a Trial T+72 forecast mean sea level pressure verifying at 12Z 27/09/93.

5.01b As Figure 5.01a but for operational T+72 forecast.

5.02 Operational mean sea level pressure analysis for 12Z 27/09/93.

5.03 Radar composite for 12Z 08/09/93 and significant weather charts for the U.K. at 12Z and 18Z 8th September 1993.

5.04a Trial T+48 forecast mean sea level pressure and total precipitation rate verifying at 12Z 8/9/93.

5.04b As 5.04a but for the operational T+48 forecast.

5.05 Meteosat infrared satellite imagery over Africa at 12Z 8/9/93.

5.06 Cloud chart showing the mean difference in level 1 cloud (trial-operational) in the Northern Hemisphere averaged from analyses over the period 12Z 10/09/93 to 12Z 21/09/92.

5.07a T+24 rainfall forecast for Africa and South America from the trial model verifying at 12Z 26/09/93.

5.07b As Figure 5.07a but for the operational forecast.

5.08 Meteosat infrared satellite imagery over Africa at 12Z 26/09/93.

5.09a T+24 rainfall forecast for the Indian Ocean, South Pacific, Asia and Australia from the trial model verifying at 12z 21/09/93.

5.09b As Figure 5.09a but for the operational forecast.

5.10 Meteosat infrared satellite imagery over India at 12Z 21/09/93.

5.11a Trial T+72 forecast mean sea level pressure for the Southern Hemisphere, verifying at 12Z 23/09/93

5.11b As Figure 5.11a but for the operational forecast.

5.12 Mean sea level pressure analysis for the Southern Hemisphere for 12Z 23/09/93 from the parallel suite.

5.13 Cloud chart showing the mean level 1 cloud differences (trial-operational) in the Southern Hemisphere averaged from analyses during the period 12z 10/09/93-21/09/93.

5.14a Cross section showing zonal mean temperature differences (trial-operational) at 10 standard levels between 950mb and 50mb averaged from T+36 forecasts during the period 00Z 12/09/93 - 00Z 29/09/93.

5.14b As Figure 5.14a but for T+72 forecasts averaged over the period 12Z 13/09/93 to 12Z 30/09/93.

5.15a Cross section showing zonal mean "u" wind components at 10 standard levels between 950mb and 50mb averaged from T+72 trial forecasts during the period 12Z 13/09/92 to 12Z 28/09/93.

5.15b As Figure 5.15a but for operational forecasts.

5.16a Cross section showing zonal mean "v" wind components at 10 standard levels between 950mb and 50mb from T+36 trial forecasts during the period 00Z 12/09/93 to 00Z 27/09/93.

5.16b As Figure 5.16a but for operational forecast.

5.17a Cross section showing zonal mean "v" wind components at 10 standard levels between 950mb and 50mb from T+72 trial forecasts during the period 12Z 13/09/93 to 12Z 28/09/93.

5.17b As Figure 5.17a but for operational forecasts.

5.18 Cross section showing zonal mean "v" wind components at 10 standard levels between 950mb and 50mb averaged from operational analyses during the period 12Z 10/09/93 to 12z 25/09/93.

5.19a Meridional flow wind errors in m/s at T+72 for September 1993.

5.19b Differences in zonal mean "v" wind components for T+72 (trial - operational) averaged over the period 12Z 13/09/93 to 12z 28/09/93.

5.20a Cross section showing zonal mean relative humidity differences (trial-operational)at 10 standard levels between 950mb and 50mb from T+36 trial forecasts during the period 00Z 12/09/93 to 00Z 27/09/93.

5.20b As 5.20a but for T+72 forecasts.

5.21a Mean sea level pressure forecast for T+72 from the trial model meaned over the period 12Z 13/9/93 to 12Z 1/10/93.

5.21b As Figure 5.22a but for the operational model.

5.22 Mean sea level pressure difference chart (trial -operational) for T+72 meaned over the period 12Z 13/9/93 to 12Z 1/10/93

5.23a Mean 850mb winds from the trial averaged from T+72 forecasts over the period 12Z 13/09/93 - 29/09/93.

5.23b As Figure 5.24a but for the operational model.

5.24a Mean 250mb winds from the trial averaged from T+72 forecasts over the period 12Z

13/09/93 - 29/09/93.

5.24b As Figure 5.25a but for the operational model.

5.25a Mean 850mb wind difference chart (trial-operational) averaged from T+72 forecasts over the period 12Z 13/09/93 - 29/09/93.

5.25b As Figure 5.26a but for 250mb winds.

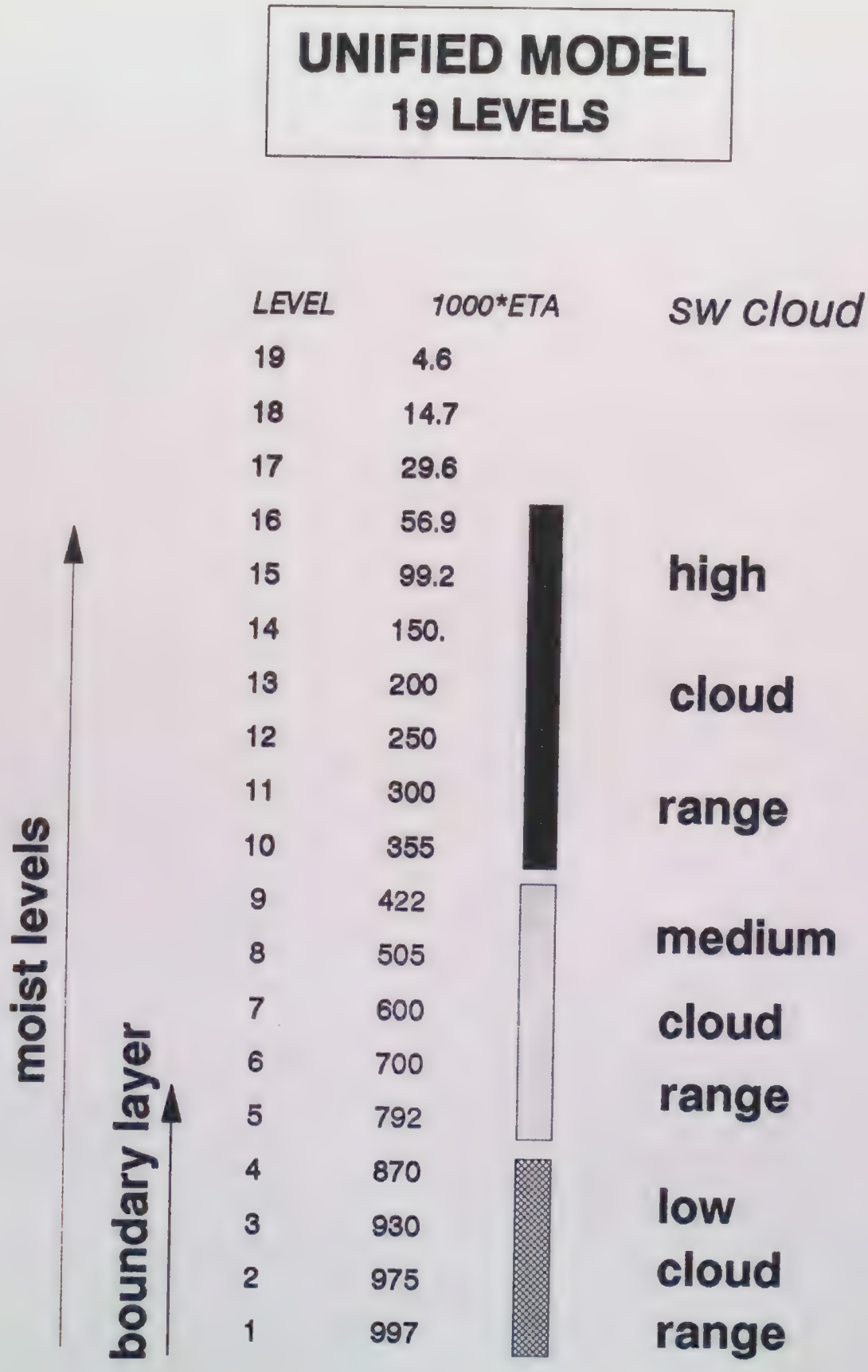
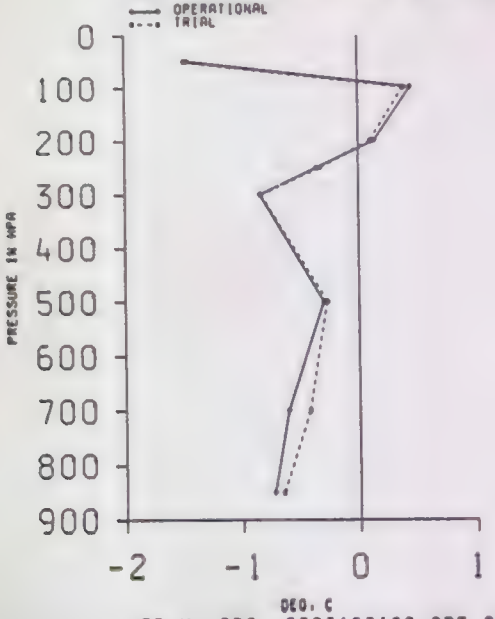
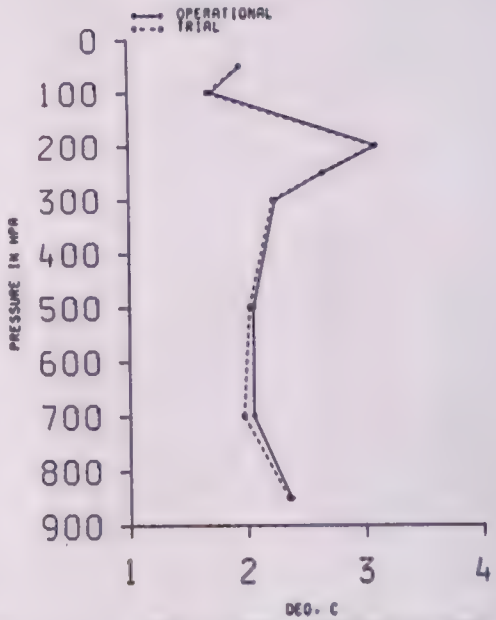

UNIFIED MODEL
19 LEVELS
LEVEL
1000*ETA
SW cloud
19 4.6
18 14.7
17 29.6
16 56.9
15 99.2
14 150.
13 200
12 250
11 300
10 355
9 422
8 505
7 600
6 700
5 792
4 870
3 930
2 975
1 997
high
cloud
range
medium
cloud
range
low
cloud
range
moist levels
boundary layer

Fig 2.1

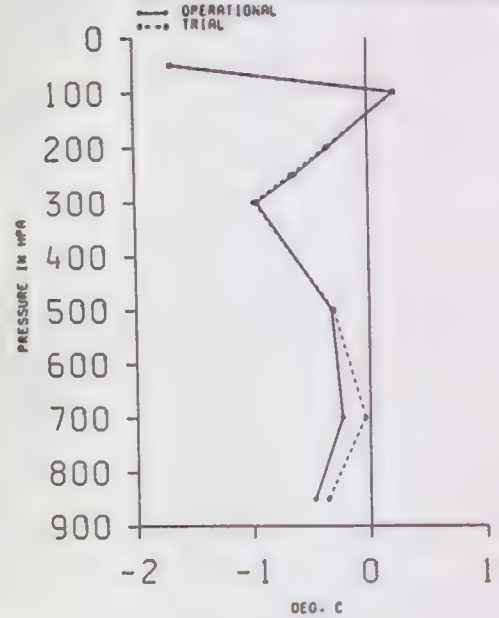
VER V. OBS STATISTICS ARE AVERAGED FROM 9/ 8/1993 TO 31/ 8/1993
MEAN STATISTICS FOR AREA 2 TEMPERATURET+72
OPER NOBS= 2613 2615 2612 2583 2569 2556 2504 1981
TRIAL NOBS= 2611 2615 2612 2583 2568 2556 2504 1981



VER V. OBS STATISTICS ARE AVERAGED FROM 9/ 8/1993 TO 31/ 8/1993
RMS STATISTICS FOR AREA 2 TEMPERATURET+72



VER V. OBS STATISTICS ARE AVERAGED FROM 9/ 8/1993 TO 31/ 8/1993
MEAN STATISTICS FOR AREA 200 TEMPERATURET+72
OPER NOBS= 6705 6915 6982 6857 6798 6756 6463 5227
TRIAL NOBS= 6704 6915 6983 6857 6798 6755 6463 5227



VER V. OBS STATISTICS ARE AVERAGED FROM 9/ 8/1993 TO 31/ 8/1993
RMS STATISTICS FOR AREA 200 TEMPERATURET+72

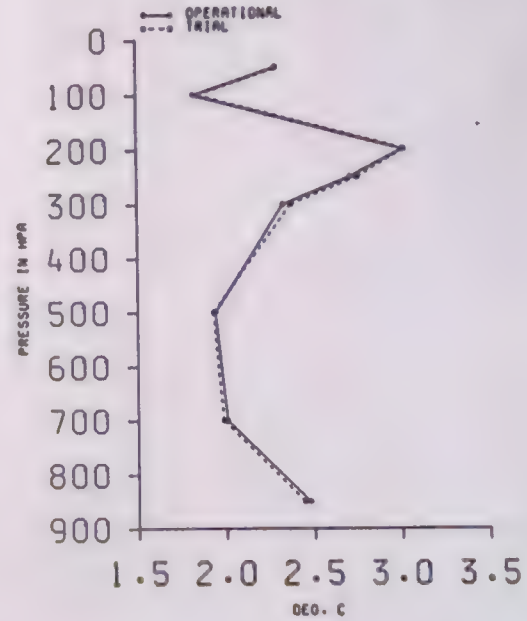
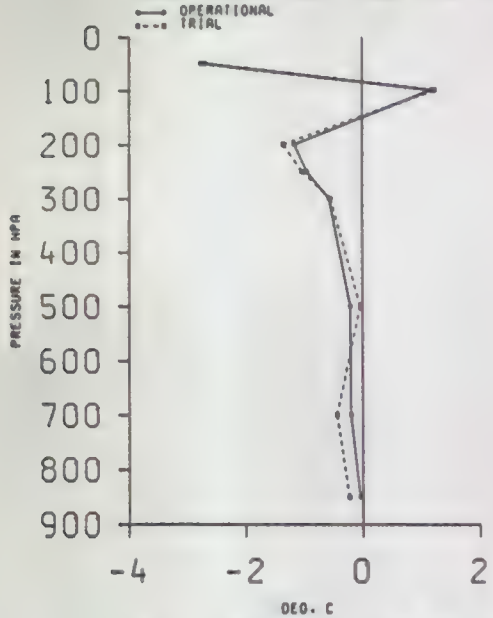
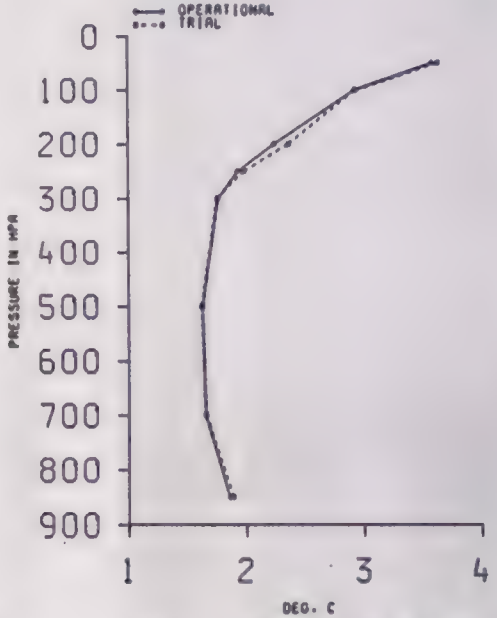


Fig 3.01

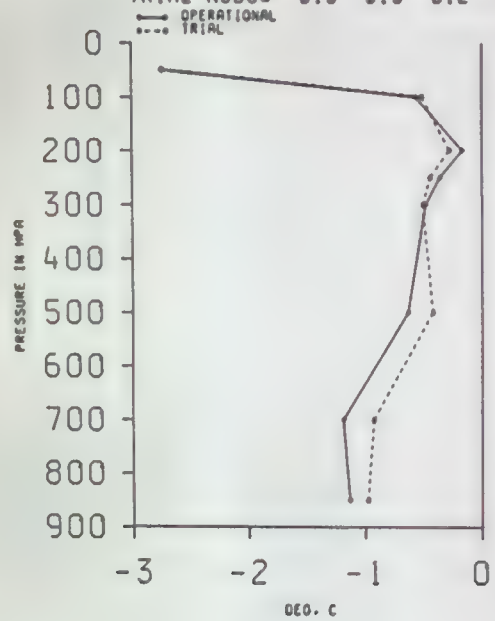
VER V. OBS STATISTICS ARE AVERAGED FROM 9/ 8/1993 TO 31/ 8/1993
MEAN STATISTICS FOR AREA 300 TEMPERATURET+72
OPER NOBS= 2649 2832 2806 2711 2653 2668 2485 1725
TRIAL NOBS= 2649 2830 2811 2713 2652 2669 2485 1724



VER V. OBS STATISTICS ARE AVERAGED FROM 9/ 8/1993 TO 31/ 8/1993
RMS STATISTICS FOR AREA 300 TEMPERATURET+72



VER V. OBS STATISTICS ARE AVERAGED FROM 9/ 8/1993 TO 31/ 8/1993
MEAN STATISTICS FOR AREA 400 TEMPERATURET+72
OPER NOBS= 513 513 513 511 509 499 486 378
TRIAL NOBS= 513 513 512 511 508 499 486 378



VER V. OBS STATISTICS ARE AVERAGED FROM 9/ 8/1993 TO 31/ 8/1993
RMS STATISTICS FOR AREA 400 TEMPERATURET+72

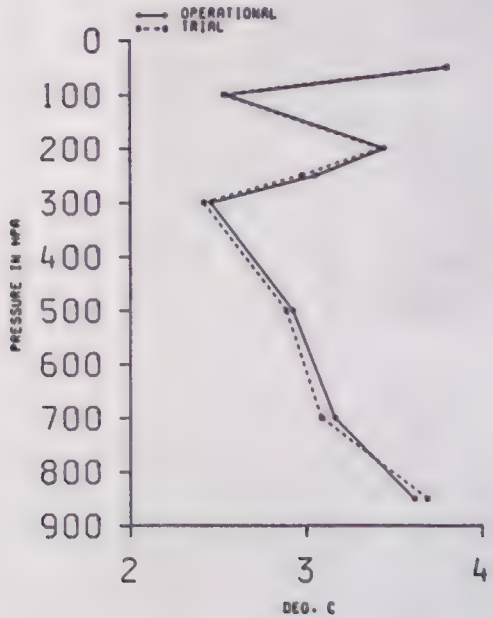
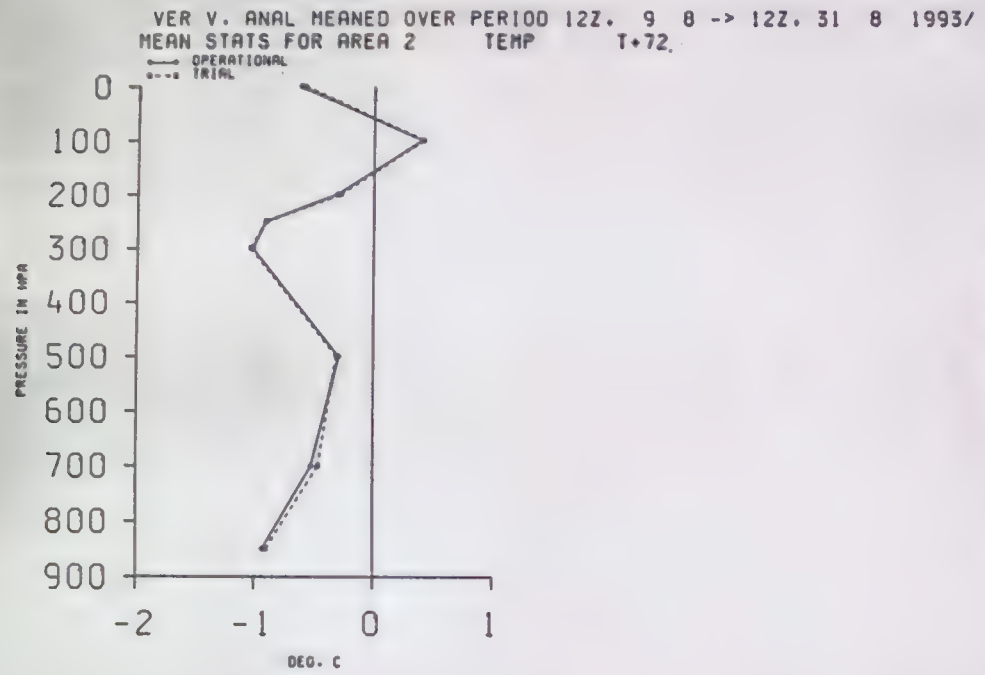
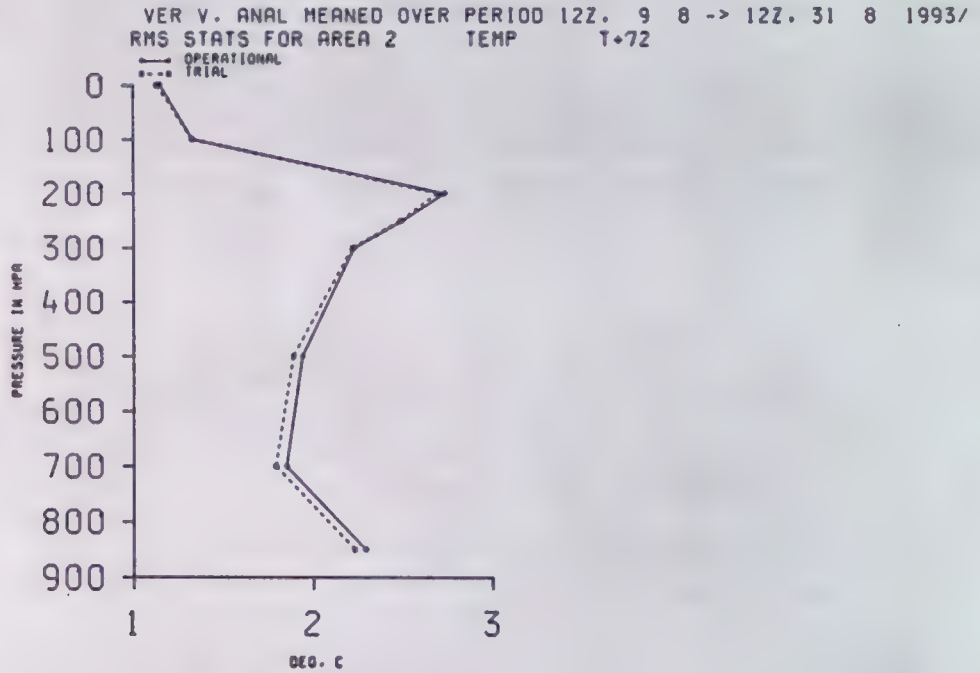


Fig 3.02


VER V. ANAL MEANED OVER PERIOD 12Z. 9 8 -> 12Z. 31 8 1993/
MEAN STATS FOR AREA 2 TEMP T+72
OPERATIONAL
TRIAL
PRESSURE IN HPA
0
100
200
300
400
500
600
700
800
900
-2
-1
0
1
DEG. C


VER V. ANAL MEANED OVER PERIOD 12Z. 9 8 -> 12Z. 31 8 1993/
RMS STATS FOR AREA 2 TEMP T+72
OPERATIONAL
TRIAL
PRESSURE IN HPA
0
100
200
300
400
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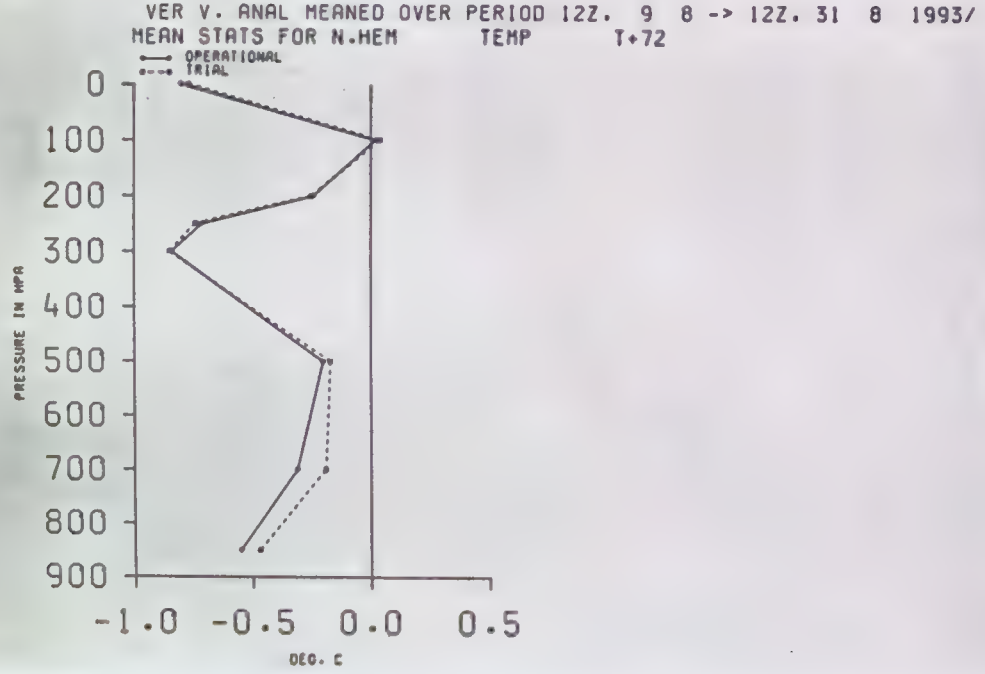
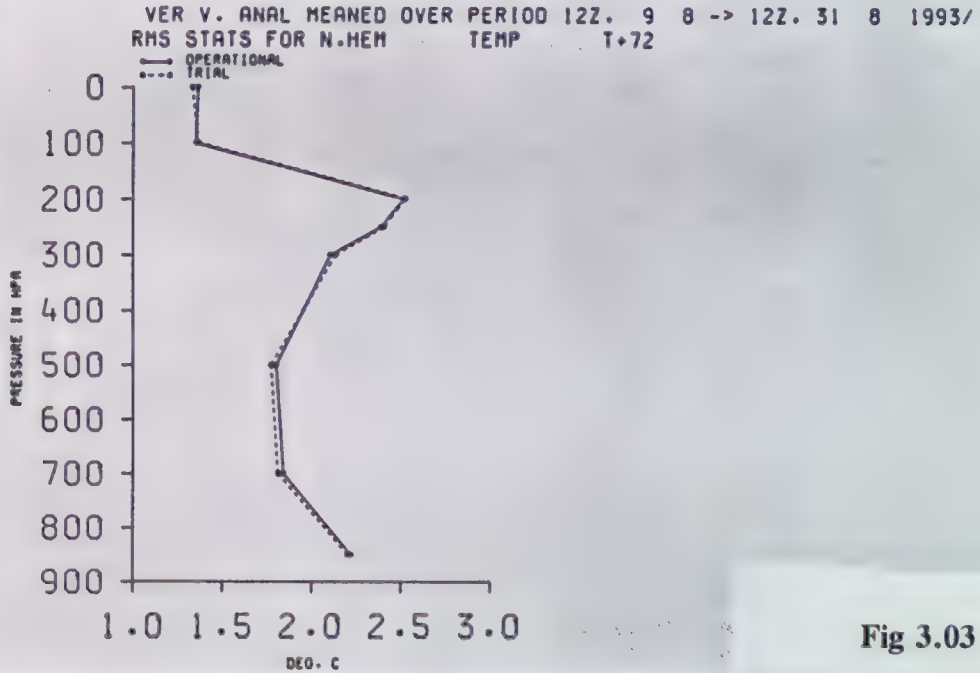
600
700
800
900
1
2
3
DEG. C


VER V. ANAL MEANED OVER PERIOD 12Z. 9 8 -> 12Z. 31 8 1993/
MEAN STATS FOR N.HEM TEMP T+72
OPERATIONAL
TRIAL
PRESSURE IN HPA
0
100
200
300
400
500
600
700
800
900
-1.0
-0.5
0.0
0.5
DEG. C


VER V. ANAL MEANED OVER PERIOD 12Z. 9 8 -> 12Z. 31 8 1993/
RMS STATS FOR N.HEM TEMP T+72
OPERATIONAL
TRIAL
PRESSURE IN HPA
0
100
200
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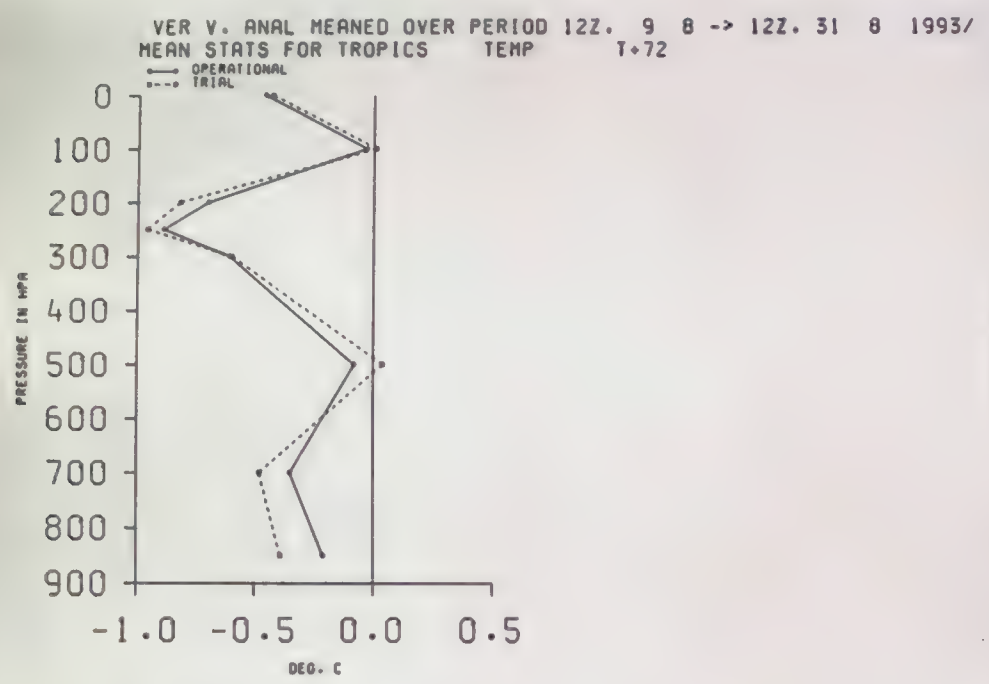
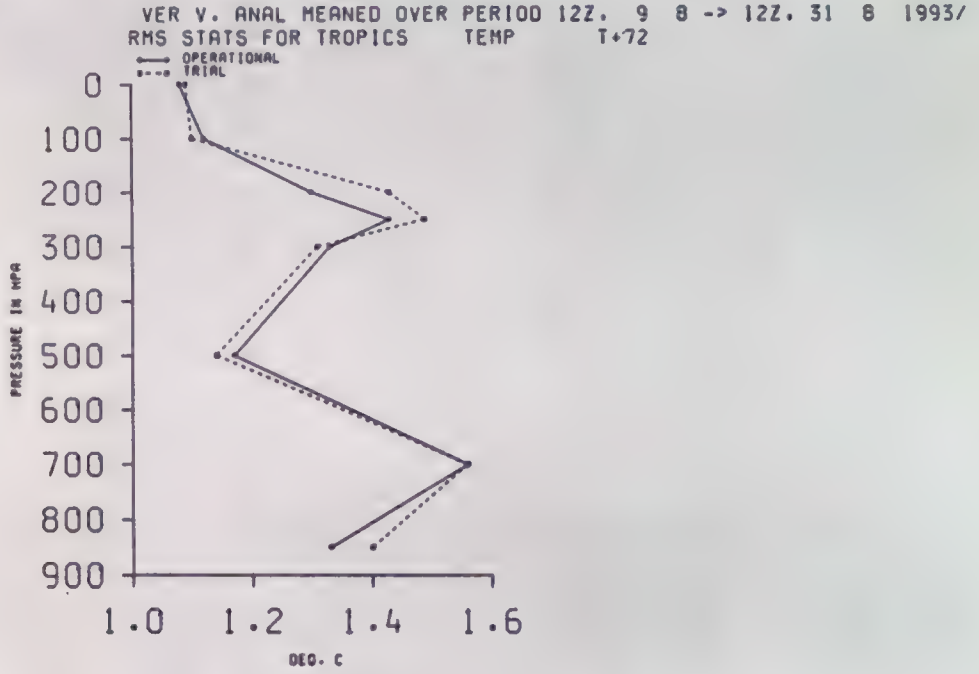
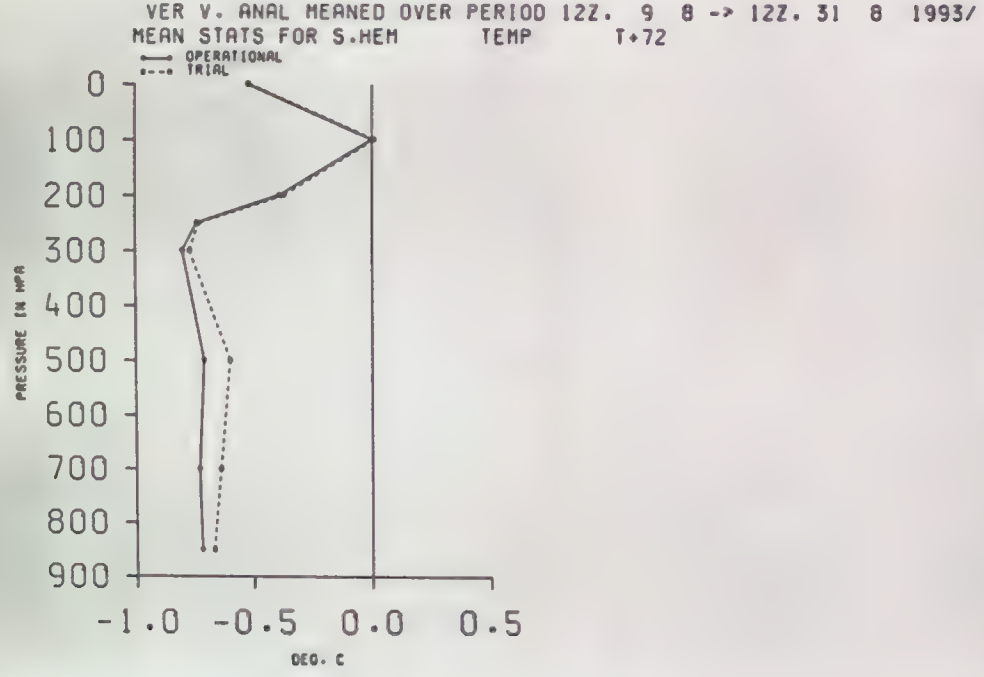
700
800
900
1.0
1.5
2.0
2.5
3.0
DEG. C

Fig 3.03


VER V. ANAL MEANED OVER PERIOD 12Z. 9 8 -> 12Z. 31 8 1993/
MEAN STATS FOR TROPICS TEMP T+72
OPERATIONAL
TRIAL
PRESSURE IN HPA
0
100
200
300
400
500
600
700
800
900
-1.0 -0.5 0.0 0.5
DEG. C


VER V. ANAL MEANED OVER PERIOD 12Z. 9 8 -> 12Z. 31 8 1993/
RMS STATS FOR TROPICS TEMP T+72
OPERATIONAL
TRIAL
PRESSURE IN HPA
0
100
200
300
400
500
600
700
800
900
1.0 1.2 1.4 1.6
DEG. C


VER V. ANAL MEANED OVER PERIOD 12Z. 9 8 -> 12Z. 31 8 1993/
MEAN STATS FOR S.HEM TEMP T+72
OPERATIONAL
TRIAL
PRESSURE IN HPA
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100
200
300
400
500
600
700
800
900
-1.0 -0.5 0.0 0.5
DEG. C

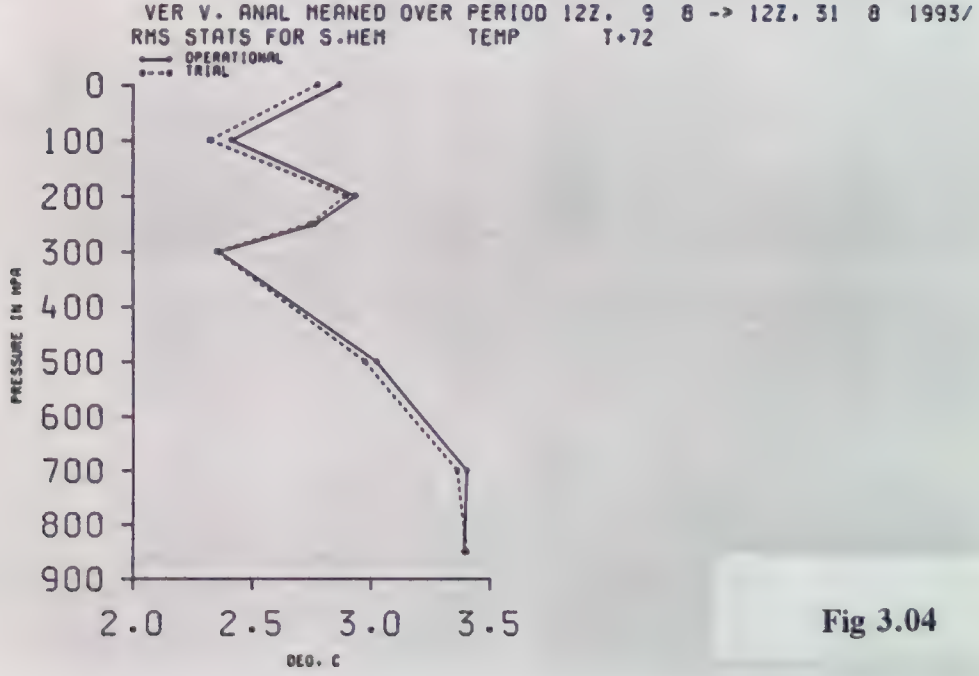
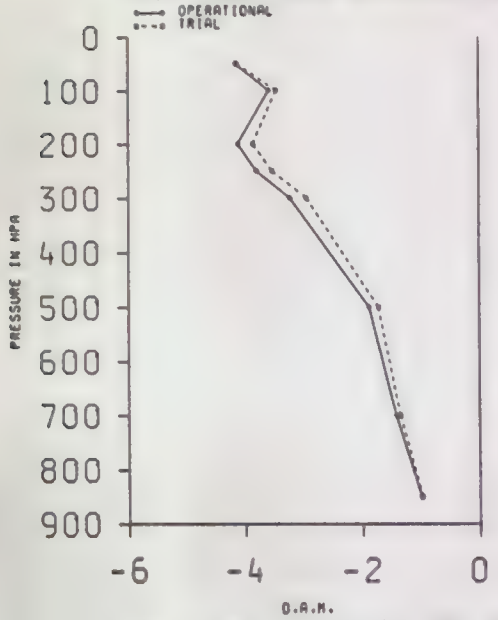
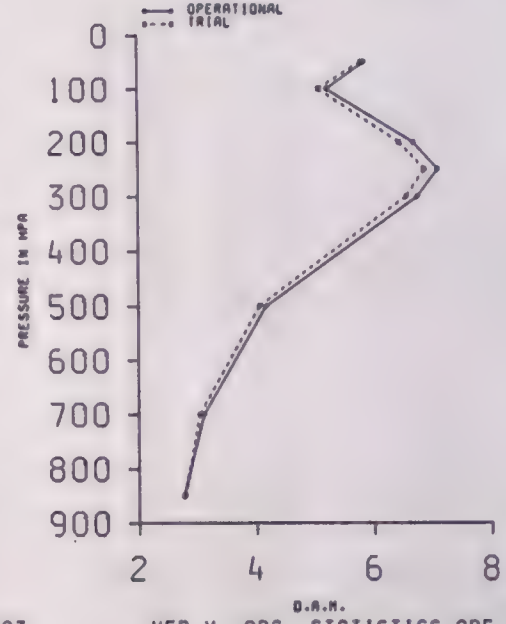

VER V. ANAL MEANED OVER PERIOD 12Z. 9 8 -> 12Z. 31 8 1993/
RMS STATS FOR S.HEM TEMP T+72
OPERATIONAL
TRIAL
PRESSURE IN HPA
0
100
200
300
400
500
600
700
800
900
2.0 2.5 3.0 3.5
DEG. C

Fig 3.04

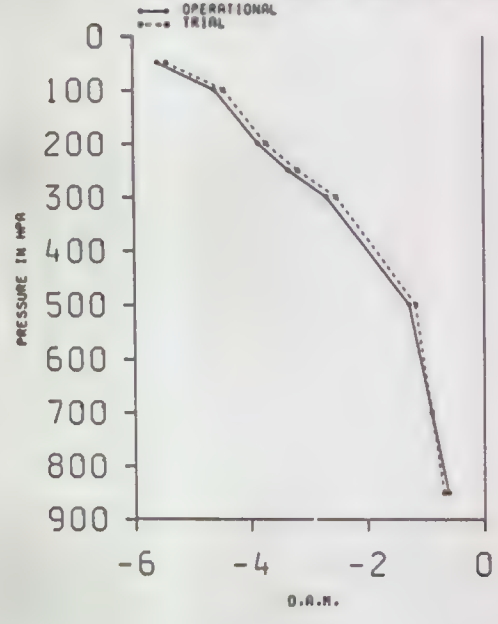
VER V. OBS STATISTICS ARE AVERAGED FROM 9/ 8/1993 TO 31/ 8/1993
MEAN STATISTICS FOR AREA 2 HEIGHT T+72
OPER NOBS= 2614 2613 2611 2584 2573 2558 2507 1989
TRIAL NOBS= 2614 2613 2611 2584 2573 2558 2507 1989



VER V. OBS STATISTICS ARE AVERAGED FROM 9/ 8/1993 TO 31/ 8/1993
RMS STATISTICS FOR AREA 2 HEIGHT T+72



VER V. OBS STATISTICS ARE AVERAGED FROM 9/ 8/1993 TO 31/ 8/1993
MEAN STATISTICS FOR AREA 200 HEIGHT T+72
OPER NOBS= 6932 6900 6985 6863 6803 6746 6435 5182
TRIAL NOBS= 6932 6901 6985 6865 6805 6746 6434 5181



VER V. OBS STATISTICS ARE AVERAGED FROM 9/ 8/1993 TO 31/ 8/1993
RMS STATISTICS FOR AREA 200 HEIGHT T+72

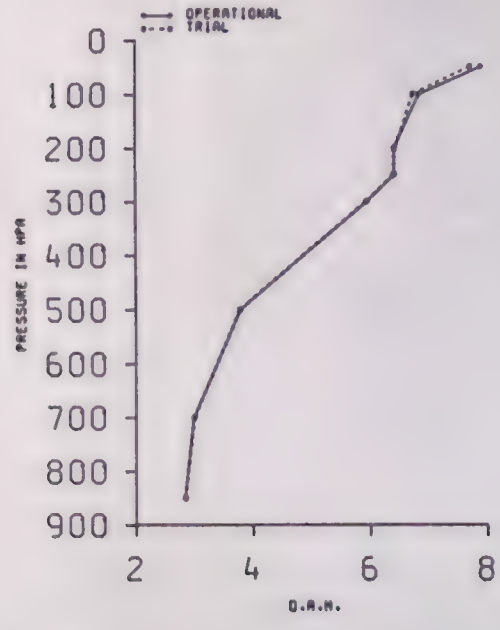
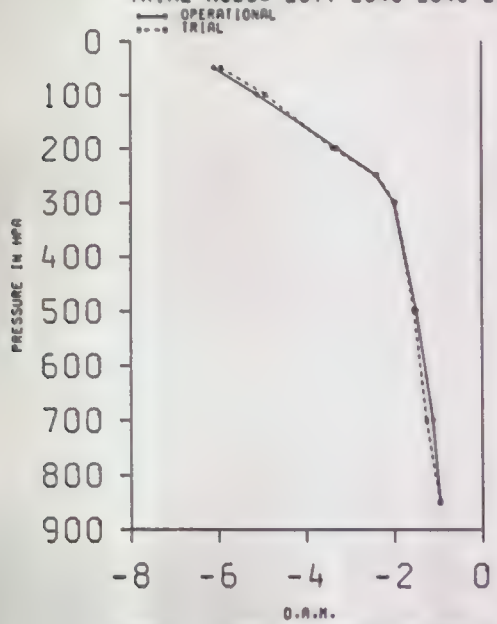
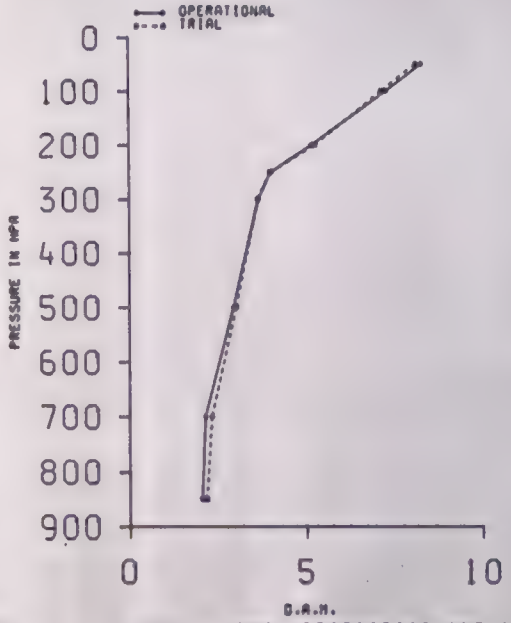


Fig 3.05

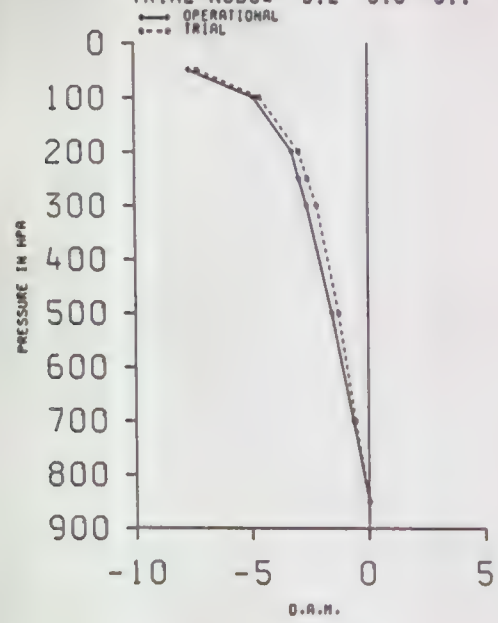
VER V. OBS STATISTICS ARE AVERAGED FROM 9/ 8/1993 TO 31/ 8/1993
MEAN STATISTICS FOR AREA 300 HEIGHT T+72
OPER NOBS= 2877 2847 2847 2676 2597 2614 2401 1698
TRIAL NOBS= 2877 2848 2848 2677 2597 2617 2401 1697



VER V. OBS STATISTICS ARE AVERAGED FROM 9/ 8/1993 TO 31/ 8/1993
RMS STATISTICS FOR AREA 300 HEIGHT T+72



VER V. OBS STATISTICS ARE AVERAGED FROM 9/ 8/1993 TO 31/ 8/1993
MEAN STATISTICS FOR AREA 400 HEIGHT T+72
OPER NOBS= 512 510 511 510 507 501 486 389
TRIAL NOBS= 512 510 511 510 507 501 486 389



VER V. OBS STATISTICS ARE AVERAGED FROM 9/ 8/1993 TO 31/ 8/1993
RMS STATISTICS FOR AREA 400 HEIGHT T+72

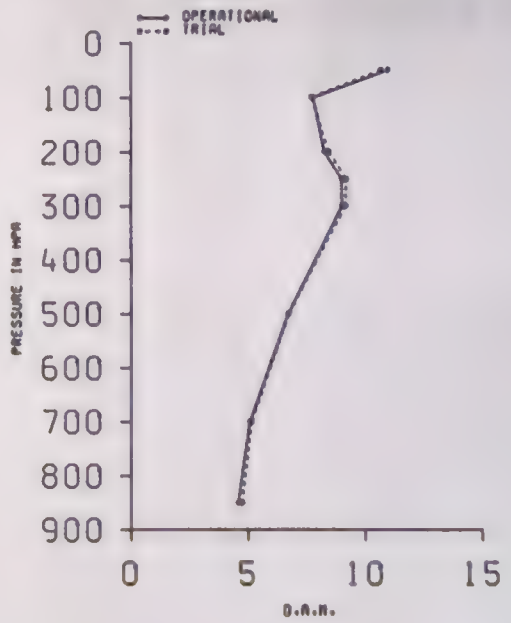
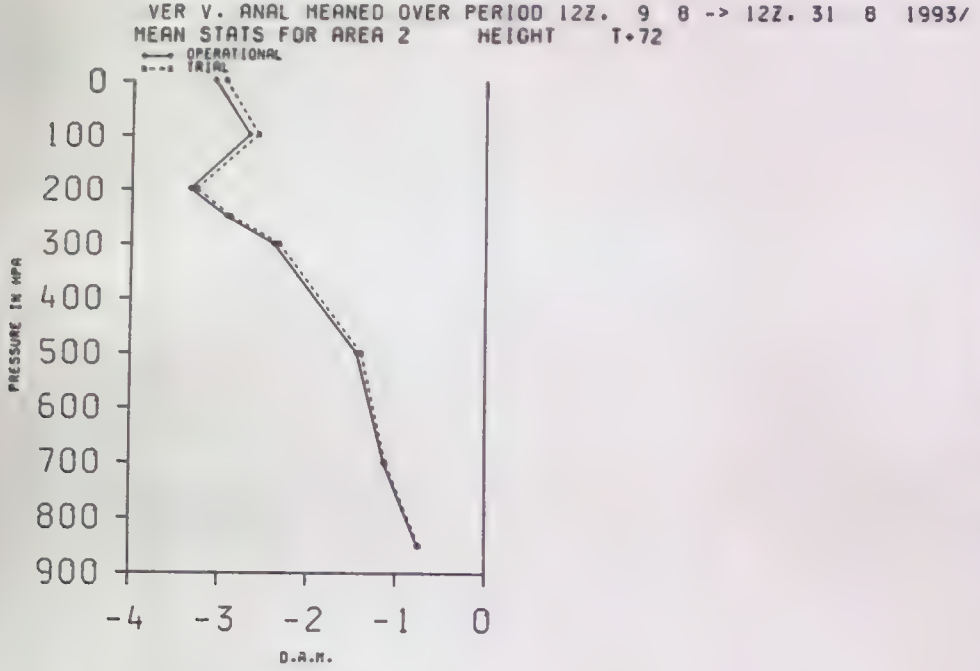
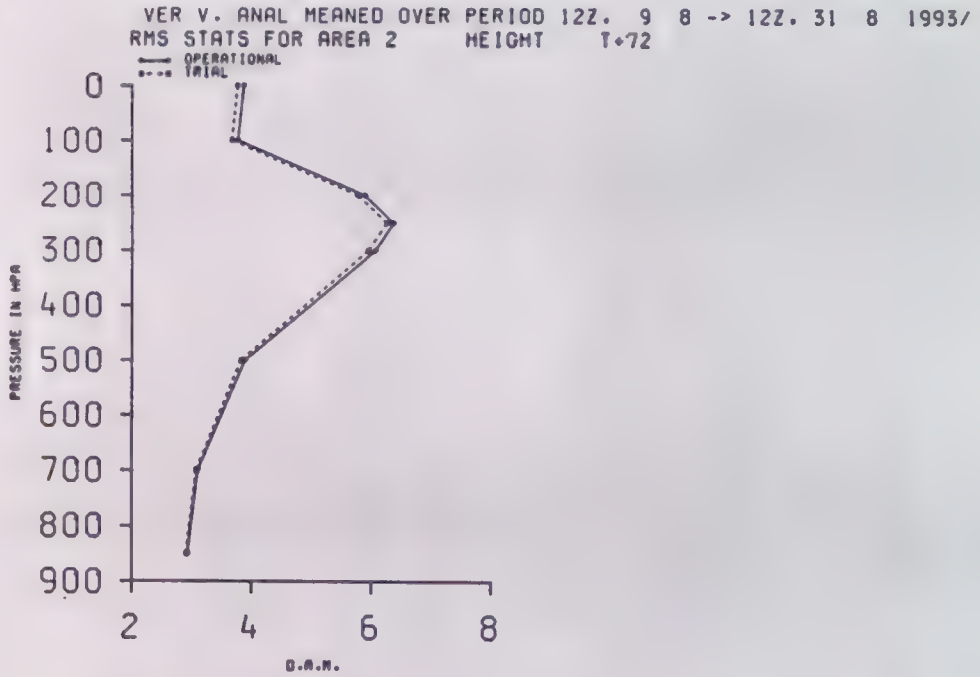
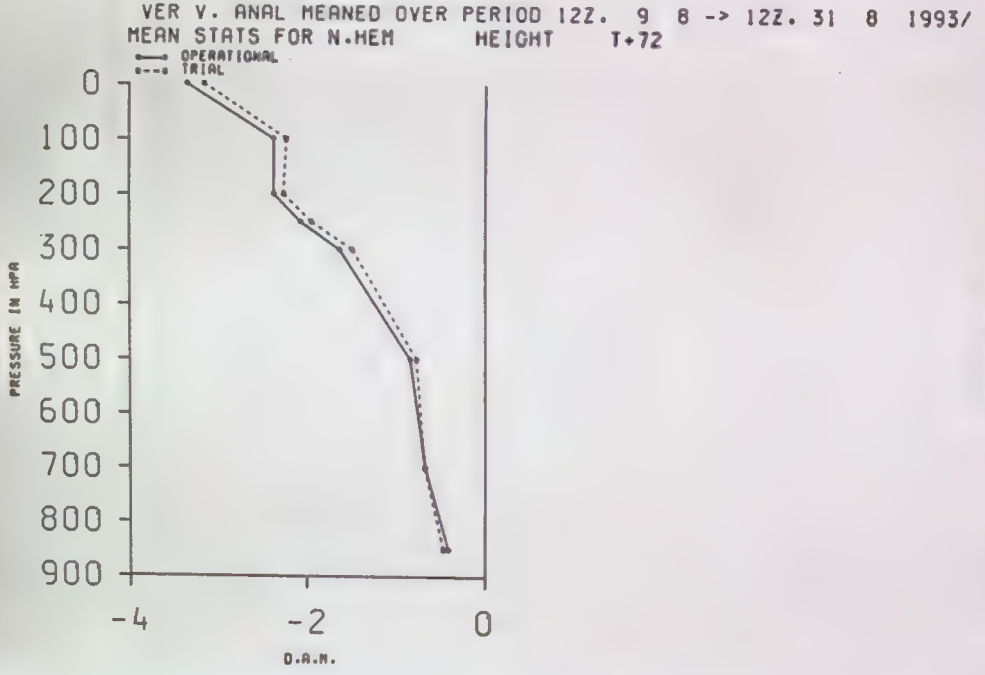


Fig 3.06

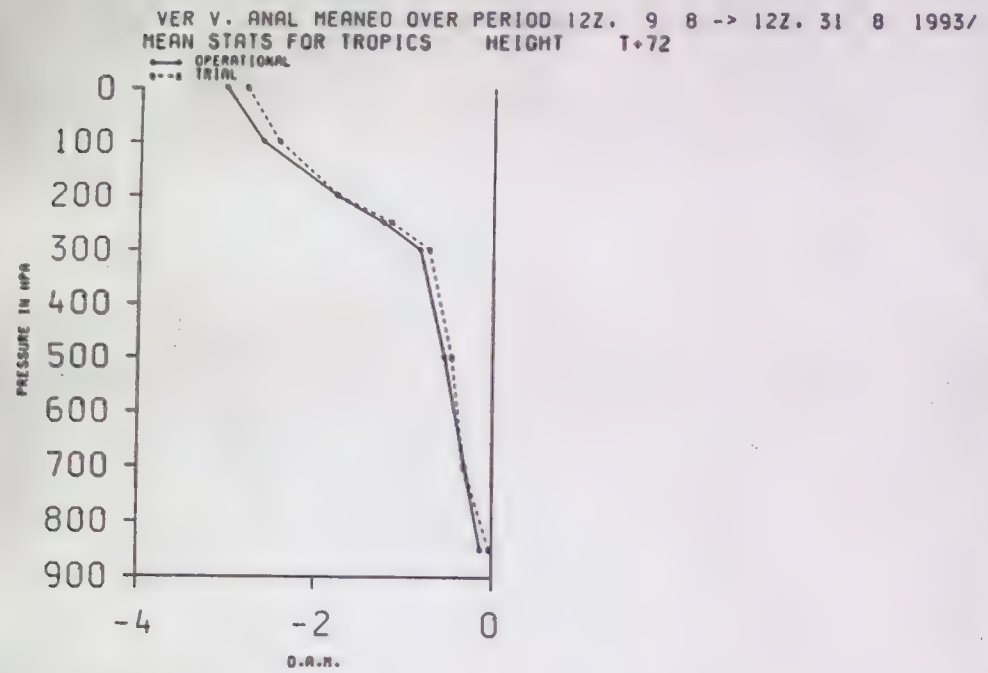

VER V. ANAL MEANED OVER PERIOD 12Z. 9 8 -> 12Z. 31 8 1993/
MEAN STATS FOR AREA 2 HEIGHT T+72
OPERATIONAL
TRIAL
PRESSURE IN HPA
0
100
200
300
400
500
600
700
800
900
-4
-3
-2
-1
0
D.A.M.

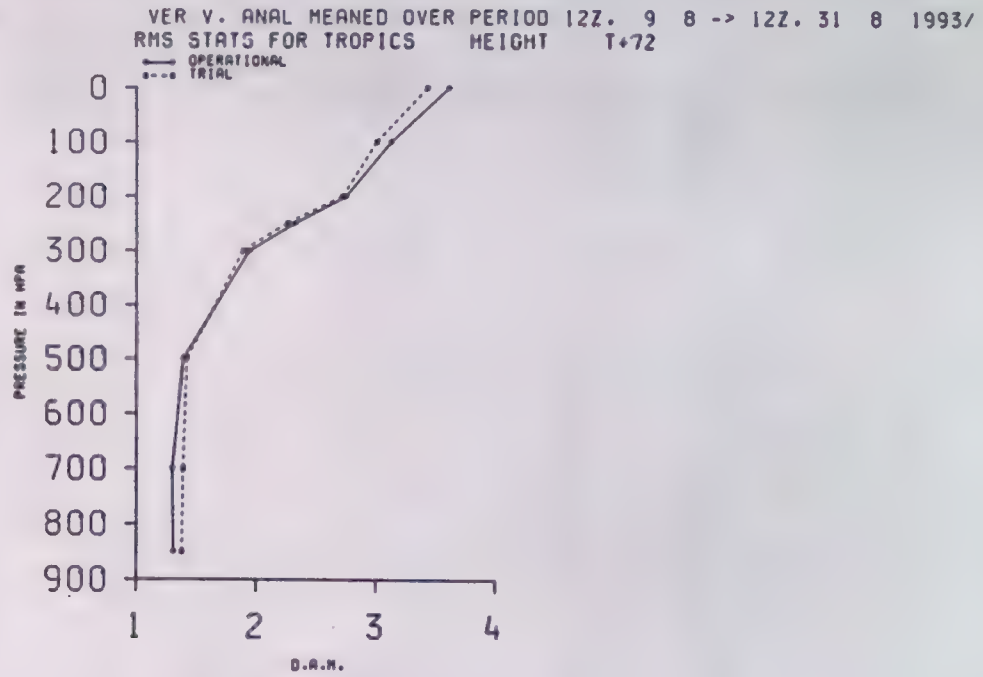

VER V. ANAL MEANED OVER PERIOD 12Z. 9 8 -> 12Z. 31 8 1993/
RMS STATS FOR AREA 2 HEIGHT T+72
OPERATIONAL
TRIAL
PRESSURE IN HPA
0
100
200
300
400
500
600
700
800
900
2
4
6
8
D.A.M.

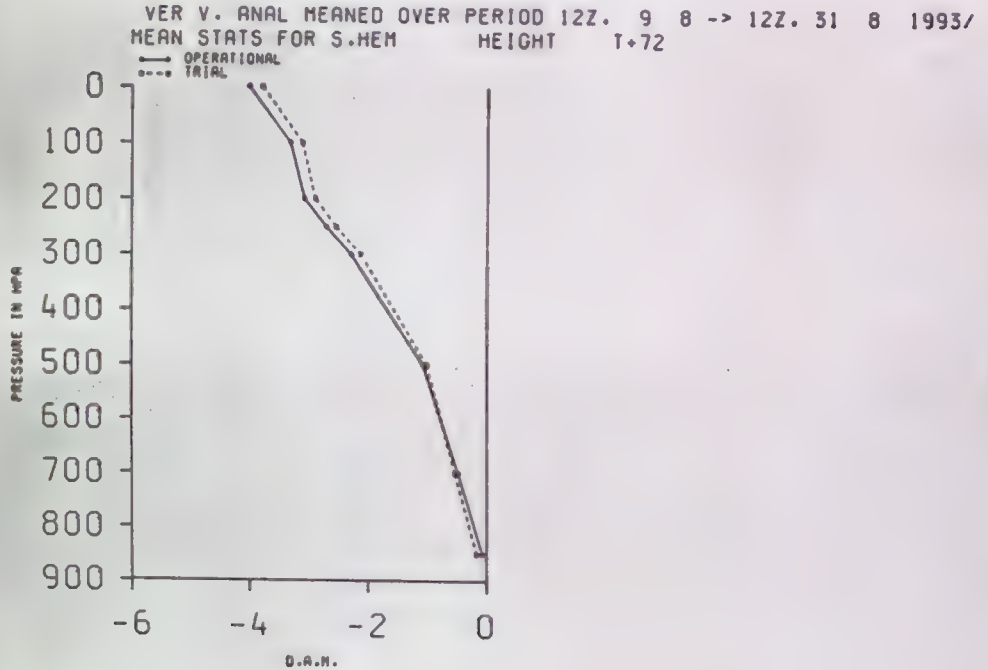

VER V. ANAL MEANED OVER PERIOD 12Z. 9 8 -> 12Z. 31 8 1993/
MEAN STATS FOR N.HEM HEIGHT T+72
OPERATIONAL
TRIAL
PRESSURE IN HPA
0
100
200
300
400
500
600
700
800
900
-4
-2
0
D.A.M.

VER V. ANAL MEANED OVER PERIOD 12Z. 9 8 -> 12Z. 31 8 1993/
RMS STATS FOR N.HEM HEIGHT T+72
OPERATIONAL
TRIAL
PRESSURE IN HPA
0
100
200
300
400
500
600
700
800
900
2
3
4
5
6
D.A.M.

Fig 3.07


VER V. ANAL MEANED OVER PERIOD 12Z. 9 8 -> 12Z. 31 8 1993/
MEAN STATS FOR TROPICS HEIGHT T+72
OPERATIONAL
TRIAL
PRESSURE IN HPA
0
100
200
300
400
500
600
700
800
900
-4
-2
0
D.A.M.


VER V. ANAL MEANED OVER PERIOD 12Z. 9 8 -> 12Z. 31 8 1993/
RMS STATS FOR TROPICS HEIGHT T+72
OPERATIONAL
TRIAL
PRESSURE IN HPA
0
100
200
300
400
500
600
700
800
900
1
2
3
4
D.A.M.


VER V. ANAL MEANED OVER PERIOD 12Z. 9 8 -> 12Z. 31 8 1993/
MEAN STATS FOR S.HEM HEIGHT T+72
OPERATIONAL
TRIAL
PRESSURE IN HPA
0
100
200
300
400
500
600
700
800
900
-6
-4
-2
0
D.A.M.

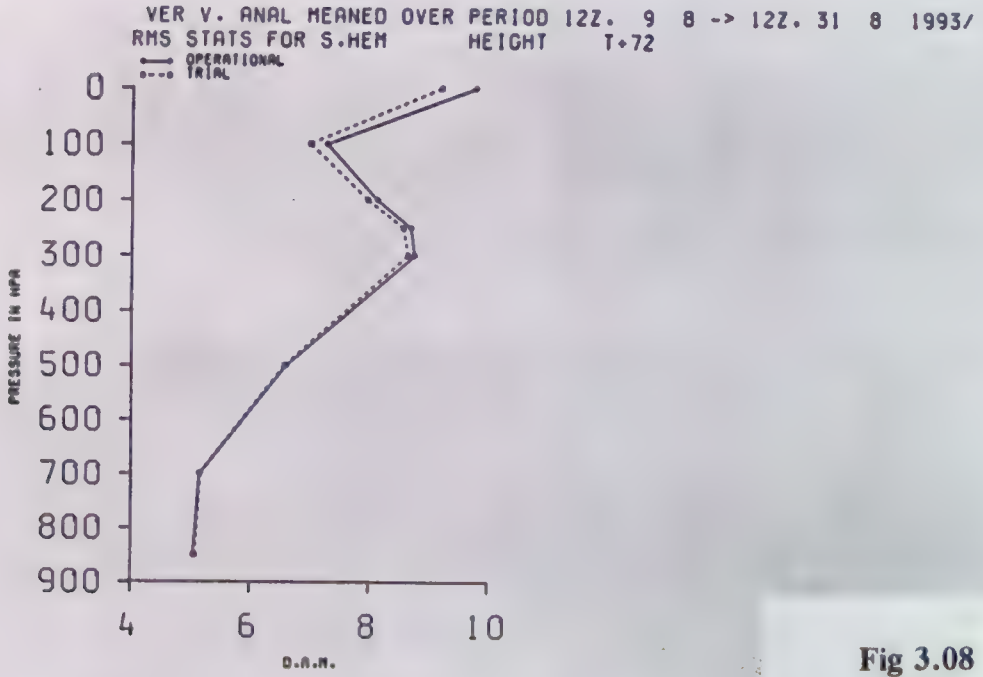
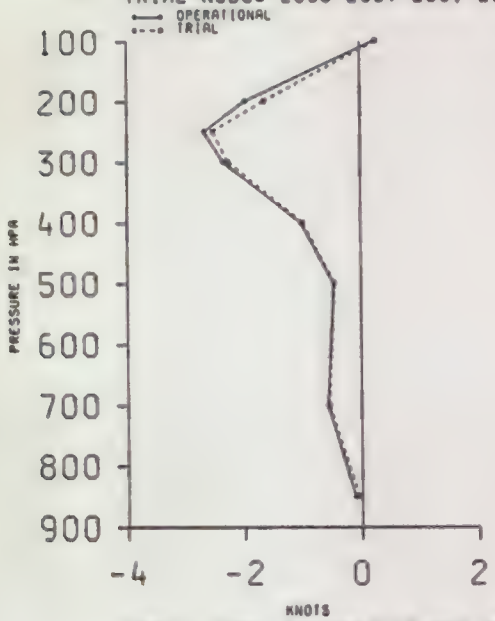
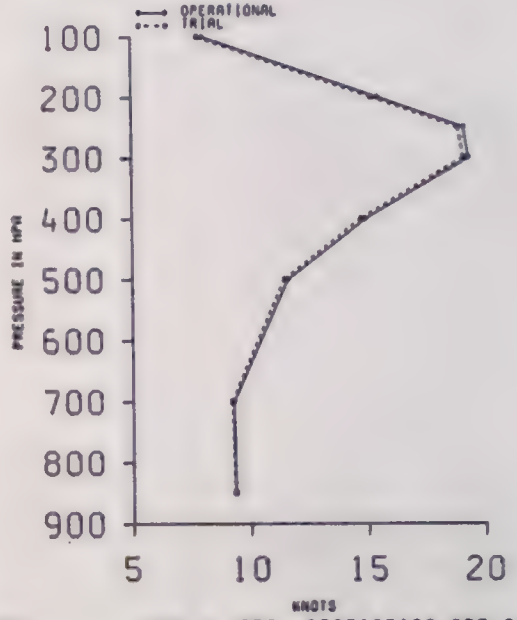

VER V. ANAL MEANED OVER PERIOD 12Z. 9 8 -> 12Z. 31 8 1993/
RMS STATS FOR S.HEM HEIGHT T+72
OPERATIONAL
TRIAL
PRESSURE IN HPA
0
100
200
300
400
500
600
700
800
900
4
6
8
10
D.A.M.

Fig 3.08

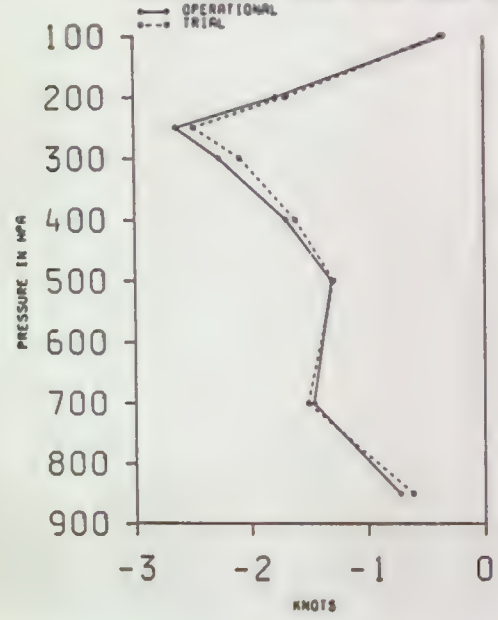
VER V. OBS STATISTICS ARE AVERAGED FROM 9/ 8/1993 TO 31/ 8/1993
MEAN STATISTICS FOR AREA 2 WIND T+48
OPER NOBS= 2536 2537 2551 2537 2506 2499 2473 2402
TRIAL NOBS= 2536 2537 2551 2537 2507 2500 2473 2402



VER V. OBS STATISTICS ARE AVERAGED FROM 9/ 8/1993 TO 31/ 8/1993
RMS STATISTICS FOR AREA 2 WIND T+48



VER V. OBS STATISTICS ARE AVERAGED FROM 9/ 8/1993 TO 31/ 8/1993
MEAN STATISTICS FOR AREA 200 WIND T+48
OPER NOBS= 6529 6767 6869 6812 6742 6674 6580 6207
TRIAL NOBS= 6530 6766 6869 6812 6743 6675 6580 6207



VER V. OBS STATISTICS ARE AVERAGED FROM 9/ 8/1993 TO 31/ 8/1993
RMS STATISTICS FOR AREA 200 WIND T+48

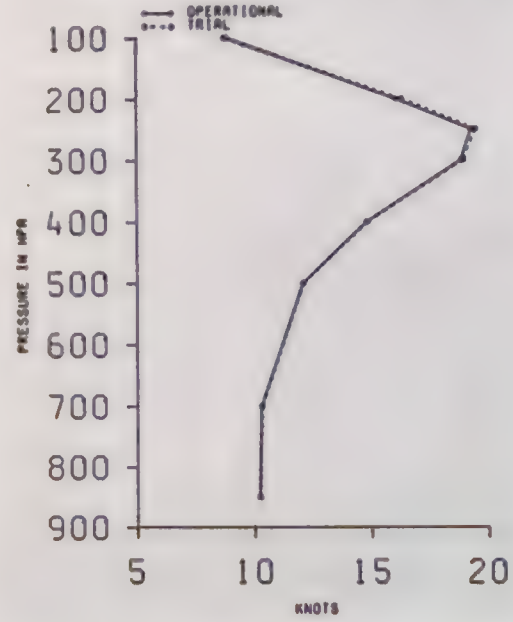
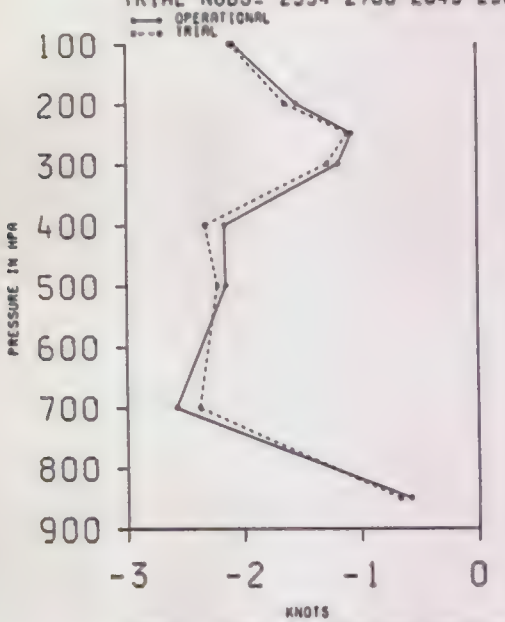
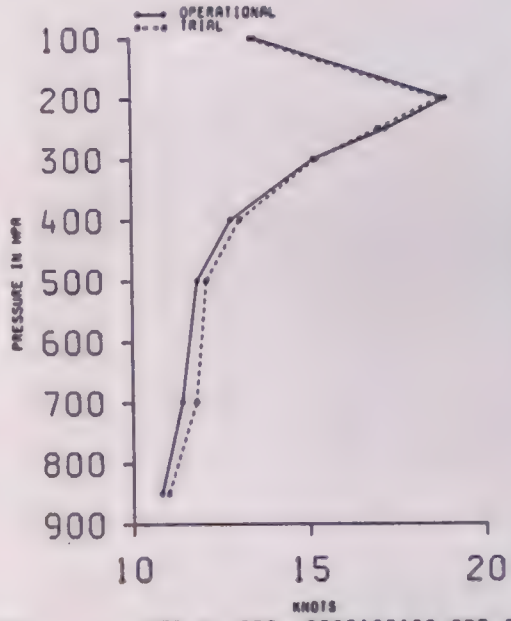


Fig 3.09

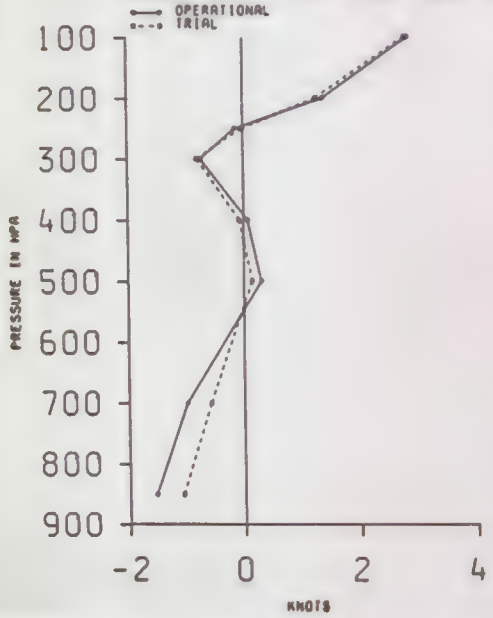
VER V. OBS STATISTICS ARE AVERAGED FROM 9/ 8/1993 TO 31/ 8/1993
MEAN STATISTICS FOR AREA 300 WIND T+48
OPER NOBS= 2553 2708 2643 2583 2527 2463 2401 2213
TRIAL NOBS= 2554 2708 2643 2584 2530 2461 2403 2213



VER V. OBS STATISTICS ARE AVERAGED FROM 9/ 8/1993 TO 31/ 8/1993
RMS STATISTICS FOR AREA 300 WIND T+48



VER V. OBS STATISTICS ARE AVERAGED FROM 9/ 8/1993 TO 31/ 8/1993
MEAN STATISTICS FOR AREA 400 WIND T+48
OPER NOBS= 342 338 337 336 332 331 318 311
TRIAL NOBS= 341 338 338 336 332 331 317 311



VER V. OBS STATISTICS ARE AVERAGED FROM 9/ 8/1993 TO 31/ 8/1993
RMS STATISTICS FOR AREA 400 WIND T+48

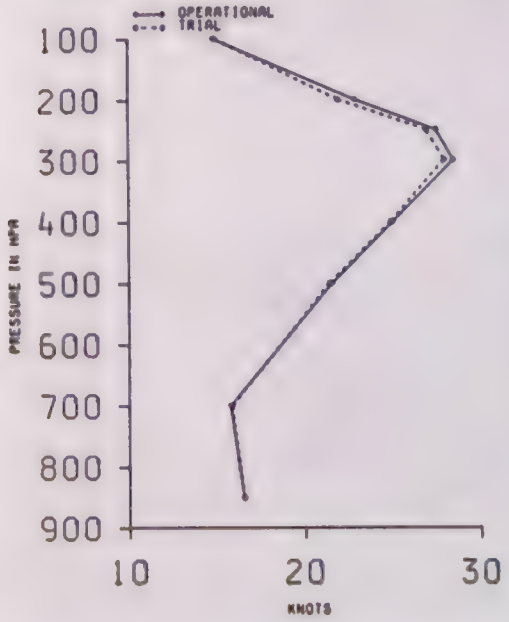
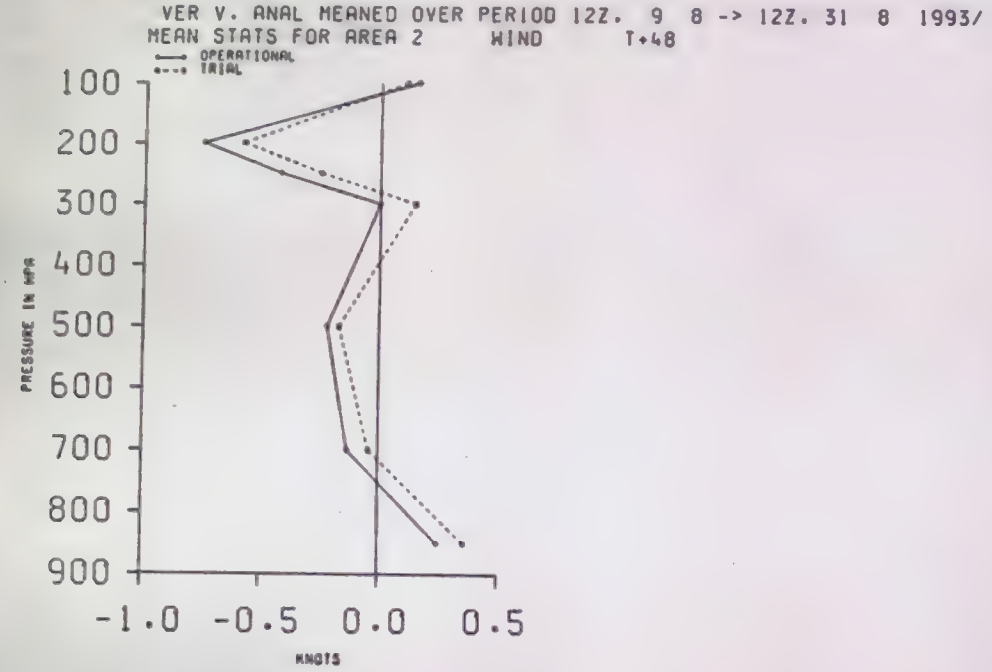
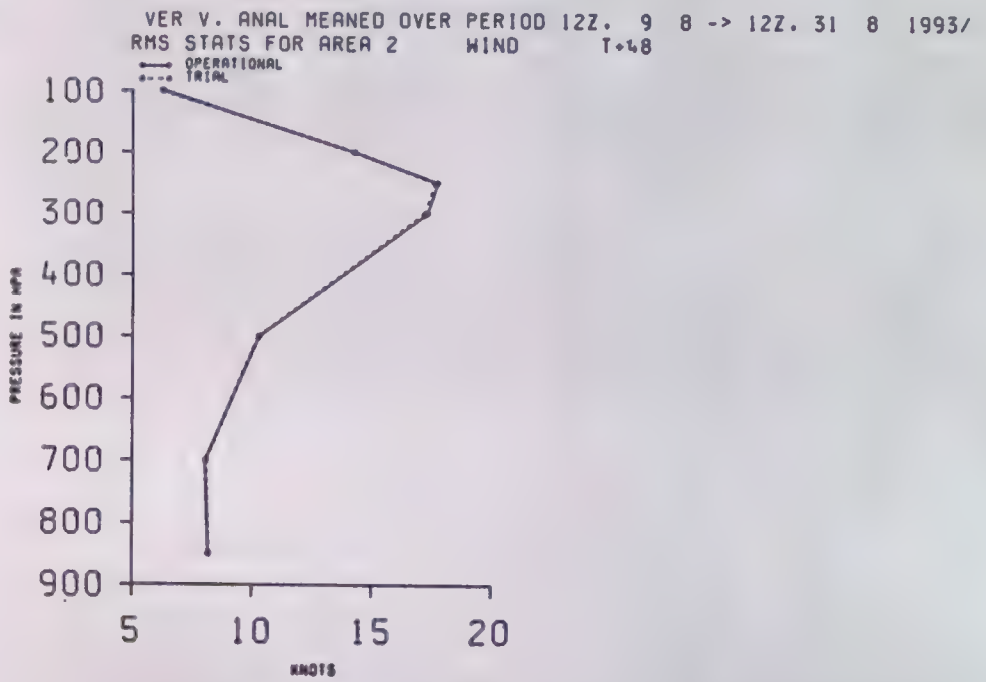
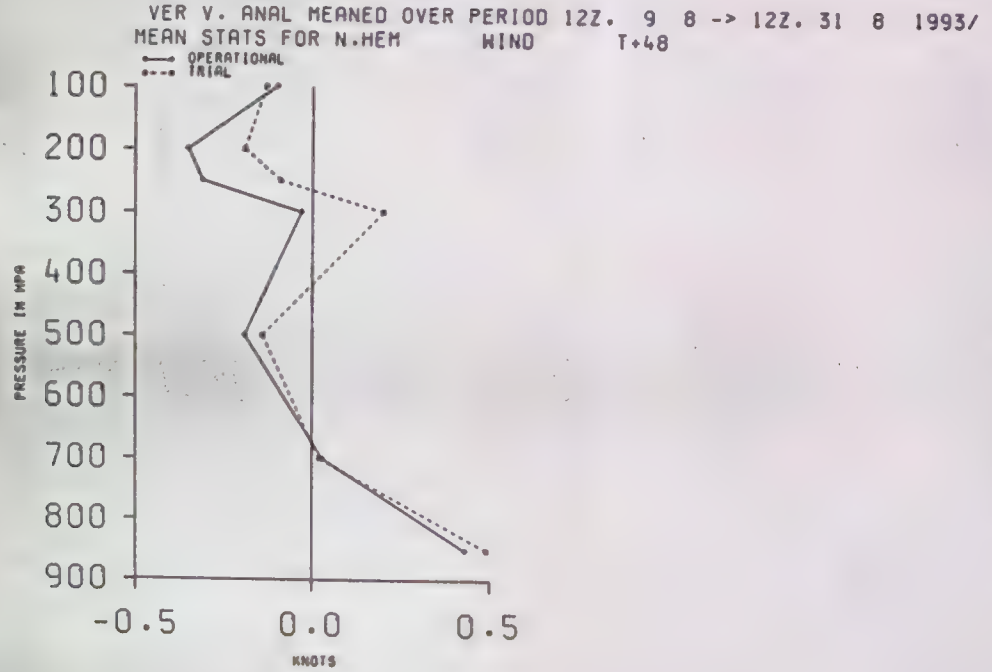


Fig 3.10


VER V. ANAL MEANED OVER PERIOD 12Z. 9 8 -> 12Z. 31 8 1993/
MEAN STATS FOR AREA 2 WIND T+48
OPERATIONAL
TRIAL
PRESSURE IN HPA
100
200
300
400
500
600
700
800
900
-1.0 -0.5 0.0 0.5
KNOTS


VER V. ANAL MEANED OVER PERIOD 12Z. 9 8 -> 12Z. 31 8 1993/
RMS STATS FOR AREA 2 WIND T+48
OPERATIONAL
TRIAL
PRESSURE IN HPA
100
200
300
400
500
600
700
800
900
5 10 15 20
KNOTS


VER V. ANAL MEANED OVER PERIOD 12Z. 9 8 -> 12Z. 31 8 1993/
MEAN STATS FOR N.HEM WIND T+48
OPERATIONAL
TRIAL
PRESSURE IN HPA
100
200
300
400
500
600
700
800
900
-0.5 0.0 0.5
KNOTS

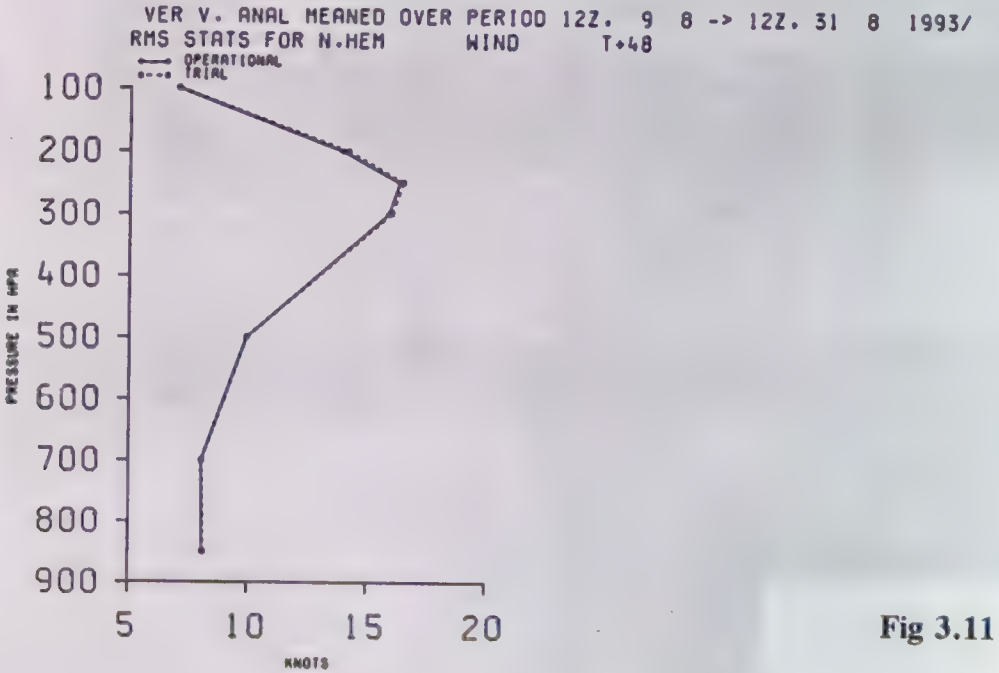
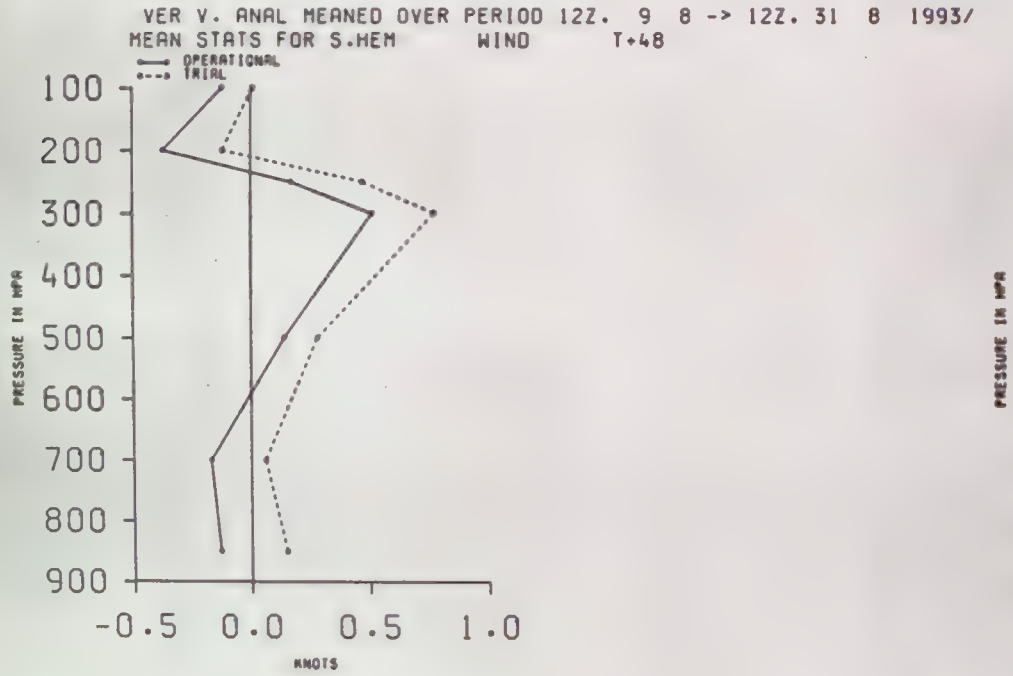

VER V. ANAL MEANED OVER PERIOD 12Z. 9 8 -> 12Z. 31 8 1993/
RMS STATS FOR N.HEM WIND T+48
OPERATIONAL
TRIAL
PRESSURE IN HPA
100
200
300
400
500
600
700
800
900
5 10 15 20
KNOTS

Fig 3.11

VER V. ANAL MEANED OVER PERIOD 12Z. 9 8 -> 12Z. 31 8 1993/
MEAN STATS FOR TROPICS WIND T+48
OPERATIONAL
TRIAL
PRESSURE IN MPA
100
200
300
400
500
600
700
800
900
0.0
0.5
1.0
1.5
KNOTS

VER V. ANAL MEANED OVER PERIOD 12Z. 9 8 -> 12Z. 31 8 1993/
RMS STATS FOR TROPICS WIND T+48
OPERATIONAL
TRIAL
PRESSURE IN MPA
100
200
300
400
500
600
700
800
900
6
8
10
12
14
KNOTS


VER V. ANAL MEANED OVER PERIOD 12Z. 9 8 -> 12Z. 31 8 1993/
MEAN STATS FOR S.HEM WIND T+48
OPERATIONAL
TRIAL
PRESSURE IN MPA
100
200
300
400
500
600
700
800
900
-0.5
0.0
0.5
1.0
KNOTS

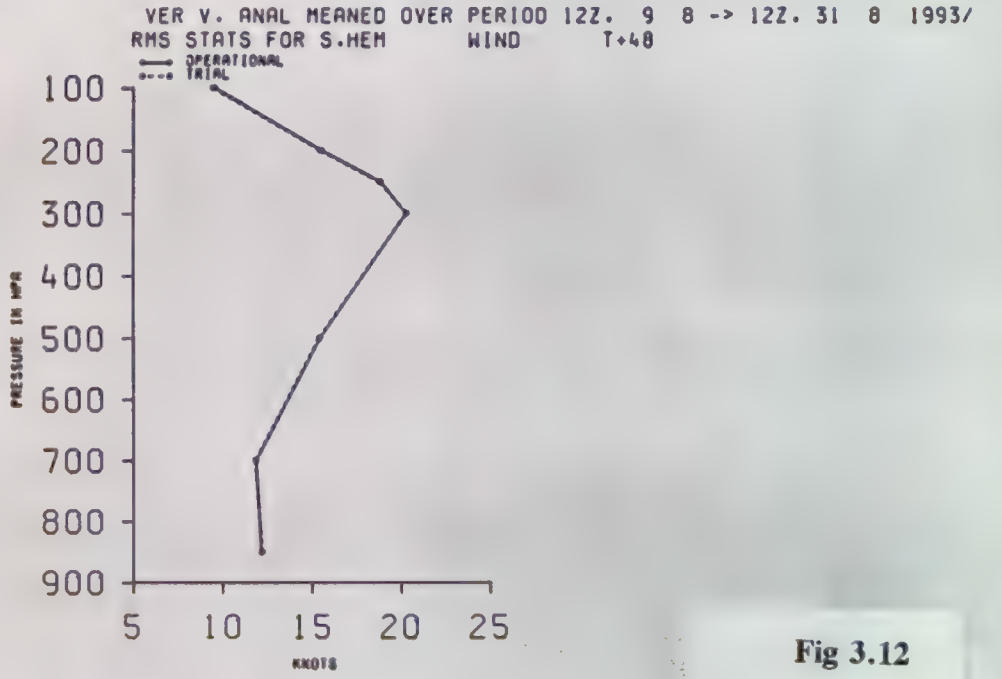
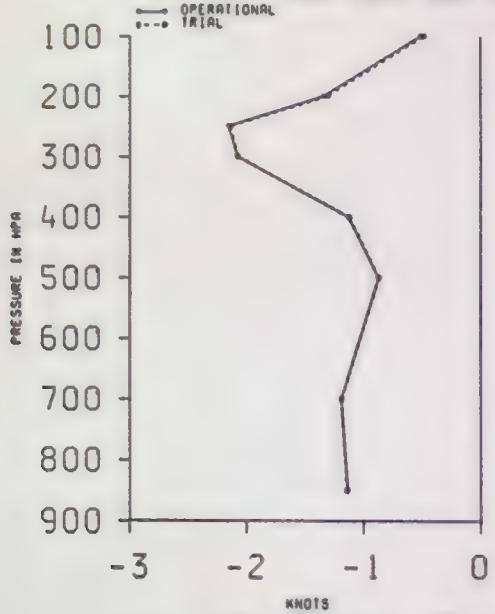
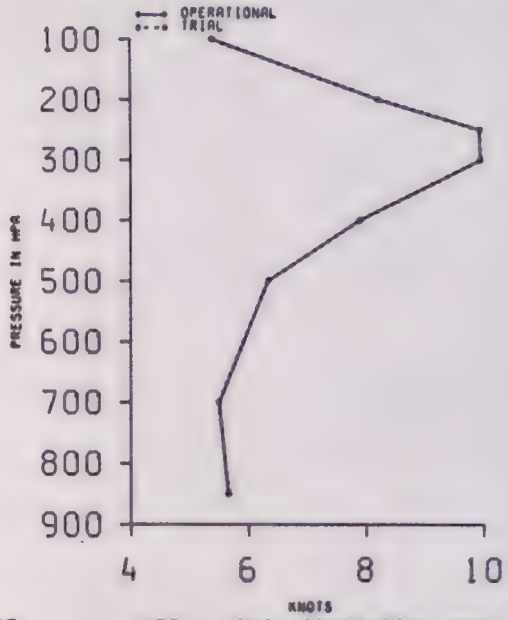

VER V. ANAL MEANED OVER PERIOD 12Z. 9 8 -> 12Z. 31 8 1993/
RMS STATS FOR S.HEM WIND T+48
OPERATIONAL
TRIAL
PRESSURE IN MPA
100
200
300
400
500
600
700
800
900
5
10
15
20
25
KNOTS

Fig 3.12

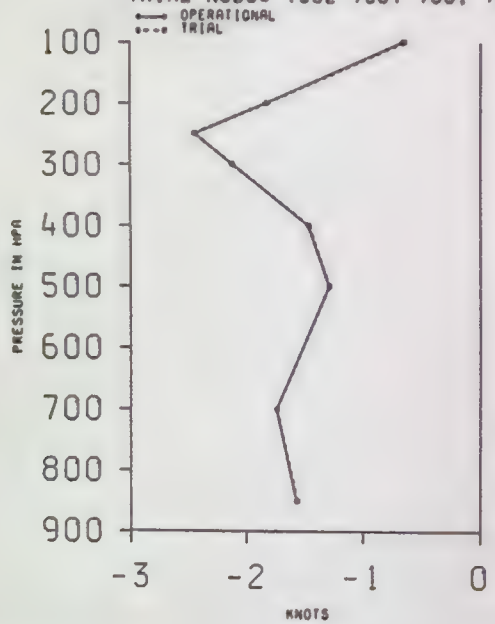
VER V. OBS STATISTICS ARE AVERAGED FROM 9/ 8/1993 TO 31/ 8/1993
MEAN STATISTICS FOR AREA 2 WIND T+0
OPER NOBS= 2843 2843 2855 2841 2807 2800 2771 2696
TRIAL NOBS= 2843 2843 2855 2841 2807 2801 2771 2696



VER V. OBS STATISTICS ARE AVERAGED FROM 9/ 8/1993 TO 31/ 8/1993
RMS STATISTICS FOR AREA 2 WIND T+0



VER V. OBS STATISTICS ARE AVERAGED FROM 9/ 8/1993 TO 31/ 8/1993
MEAN STATISTICS FOR AREA 200 WIND T+0
OPER NOBS= 7301 7568 7681 7620 7542 7469 7363 6958
TRIAL NOBS= 7302 7567 7681 7620 7542 7470 7363 6958



VER V. OBS STATISTICS ARE AVERAGED FROM 9/ 8/1993 TO 31/ 8/1993
RMS STATISTICS FOR AREA 200 WIND T+0

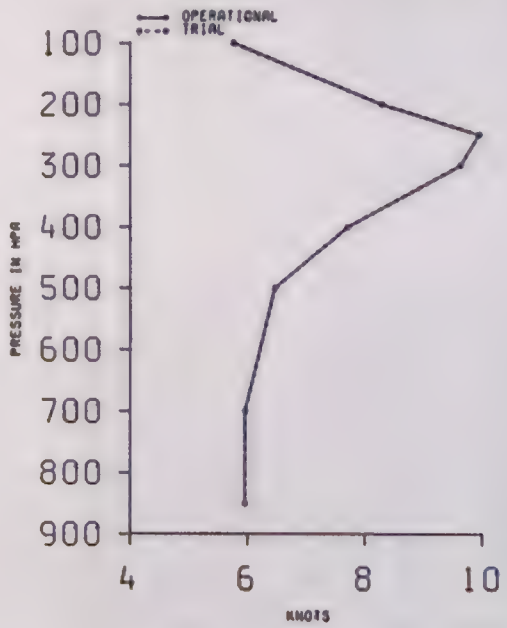
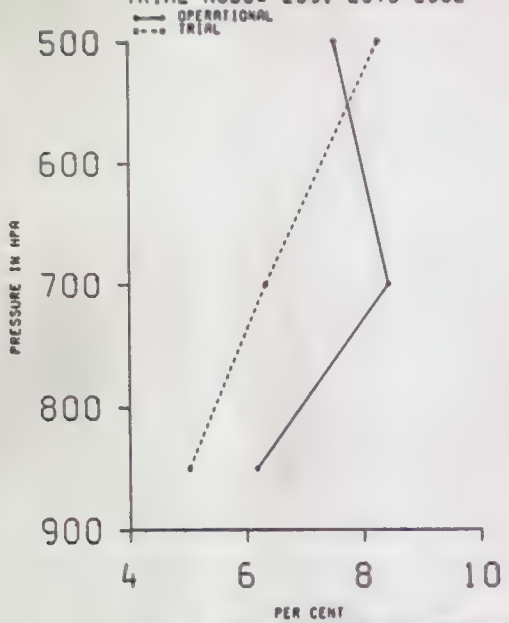
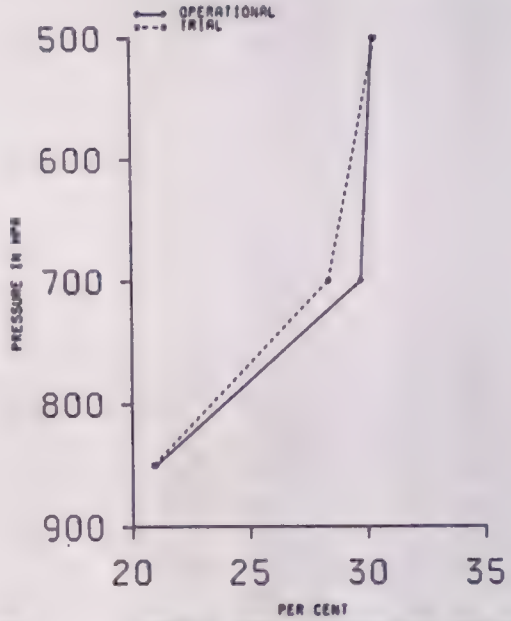


Fig 3.13

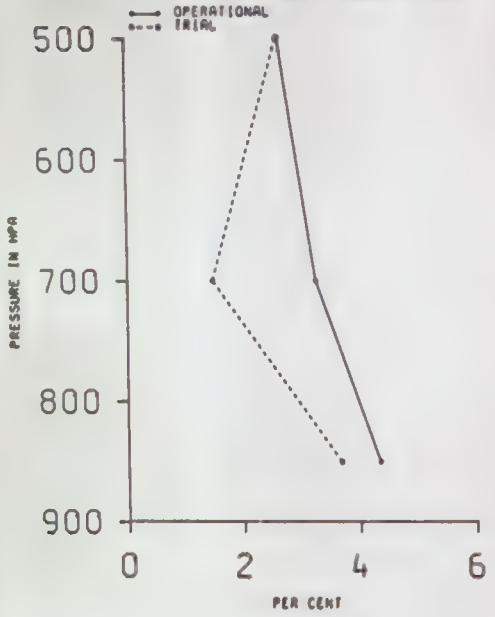
VER V. OBS STATISTICS ARE AVERAGED FROM 9/ 8/1993 TO 31/ 8/1993
MEAN STATISTICS FOR AREA 2 REL HUM T+72
OPER NOBS= 2588 2570 2586
TRIAL NOBS= 2591 2573 2582



VER V. OBS STATISTICS ARE AVERAGED FROM 9/ 8/1993 TO 31/ 8/1993
RMS STATISTICS FOR AREA 2 REL HUM T+72



VER V. OBS STATISTICS ARE AVERAGED FROM 9/ 8/1993 TO 31/ 8/1993
MEAN STATISTICS FOR AREA 200 REL HUM T+72
OPER NOBS= 6669 6824 6890
TRIAL NOBS= 6671 6828 6885



VER V. OBS STATISTICS ARE AVERAGED FROM 9/ 8/1993 TO 31/ 8/1993
RMS STATISTICS FOR AREA 200 REL HUM T+72

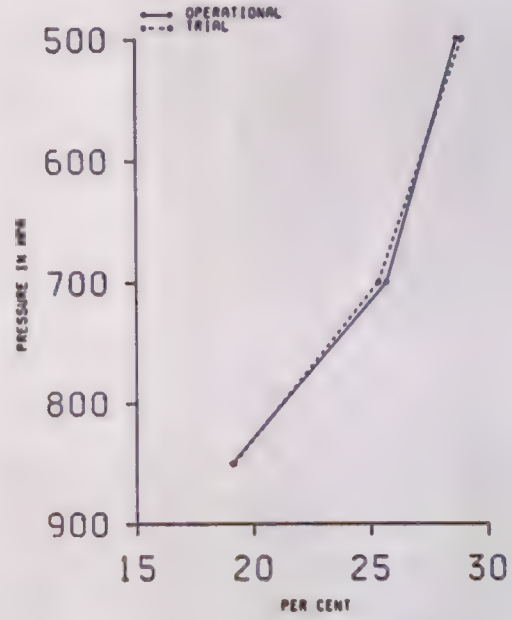
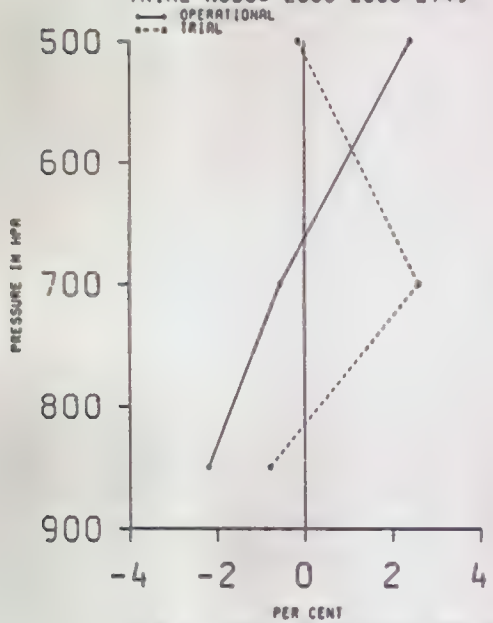
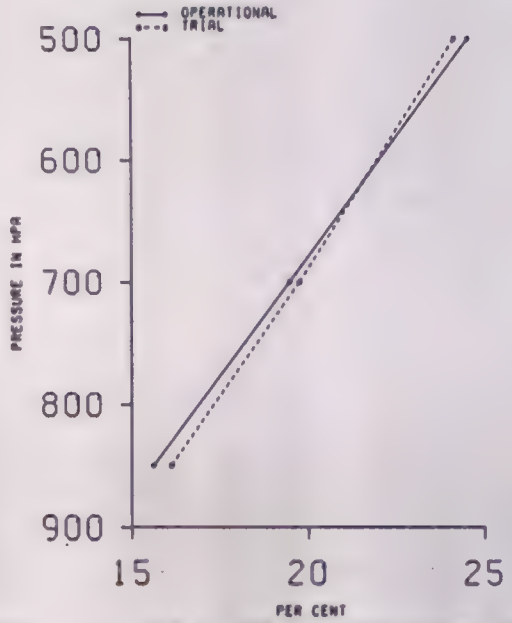


Fig 3.14

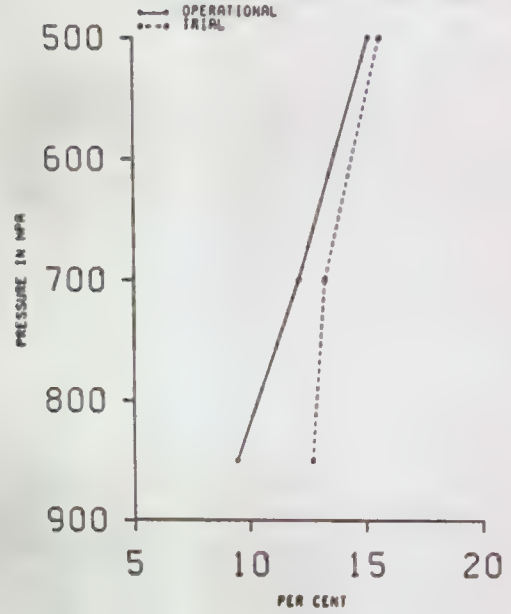
VER V. OBS STATISTICS ARE AVERAGED FROM 9/ 8/1993 TO 31/ 8/1993
MEAN STATISTICS FOR AREA 300 REL HUM T+72
OPER NOBS= 2663 2838 2748
TRIAL NOBS= 2665 2836 2749



VER V. OBS STATISTICS ARE AVERAGED FROM 9/ 8/1993 TO 31/ 8/1993
RMS STATISTICS FOR AREA 300 REL HUM T+72



VER V. OBS STATISTICS ARE AVERAGED FROM 9/ 8/1993 TO 31/ 8/1993
MEAN STATISTICS FOR AREA 400 REL HUM T+72
OPER NOBS= 508 497 479
TRIAL NOBS= 509 498 480



VER V. OBS STATISTICS ARE AVERAGED FROM 9/ 8/1993 TO 31/ 8/1993
RMS STATISTICS FOR AREA 400 REL HUM T+72

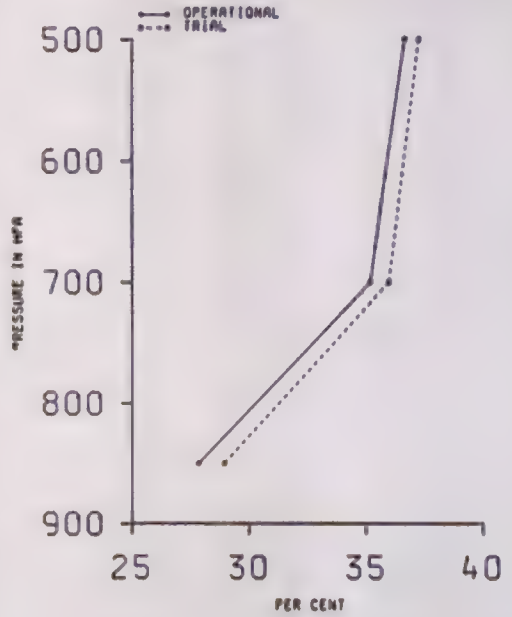
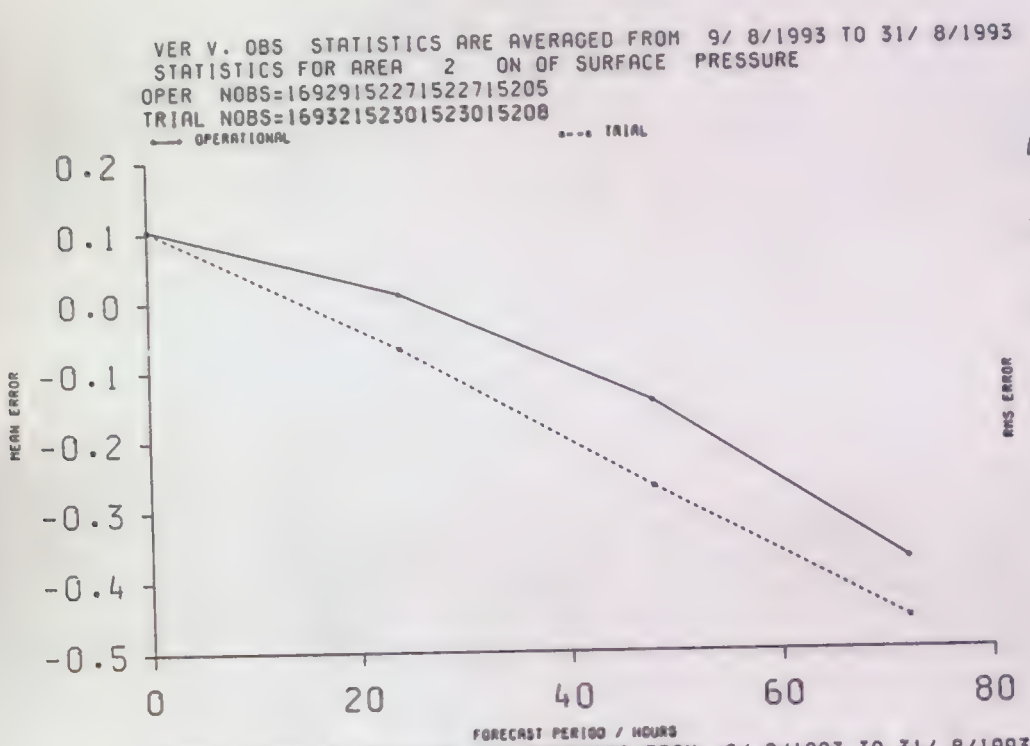
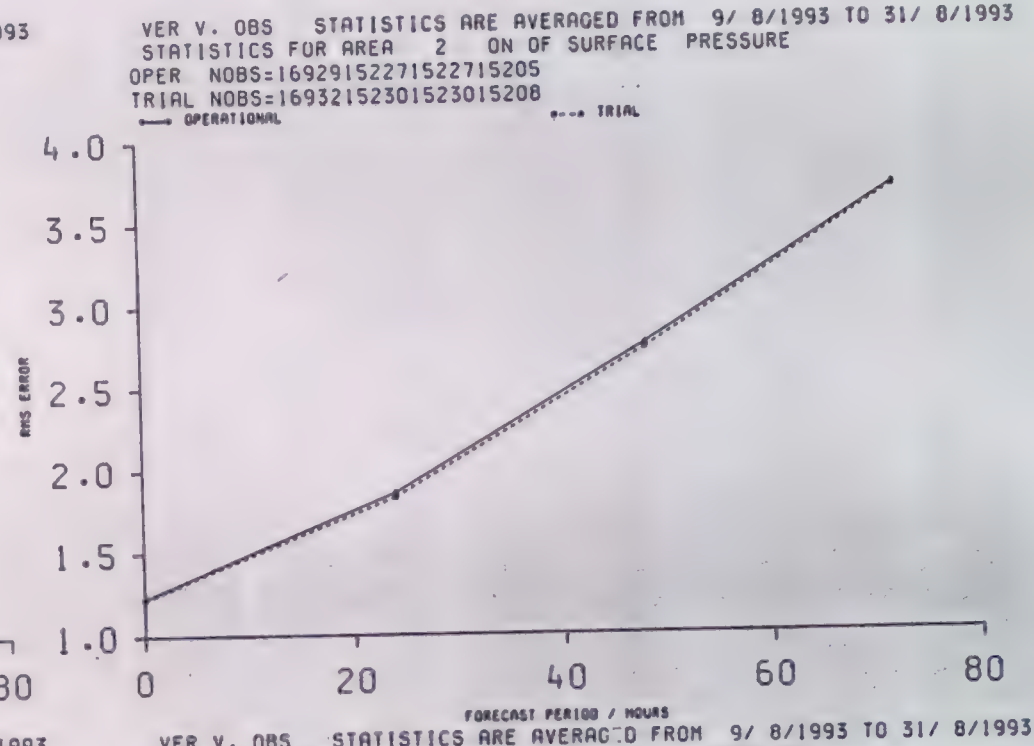
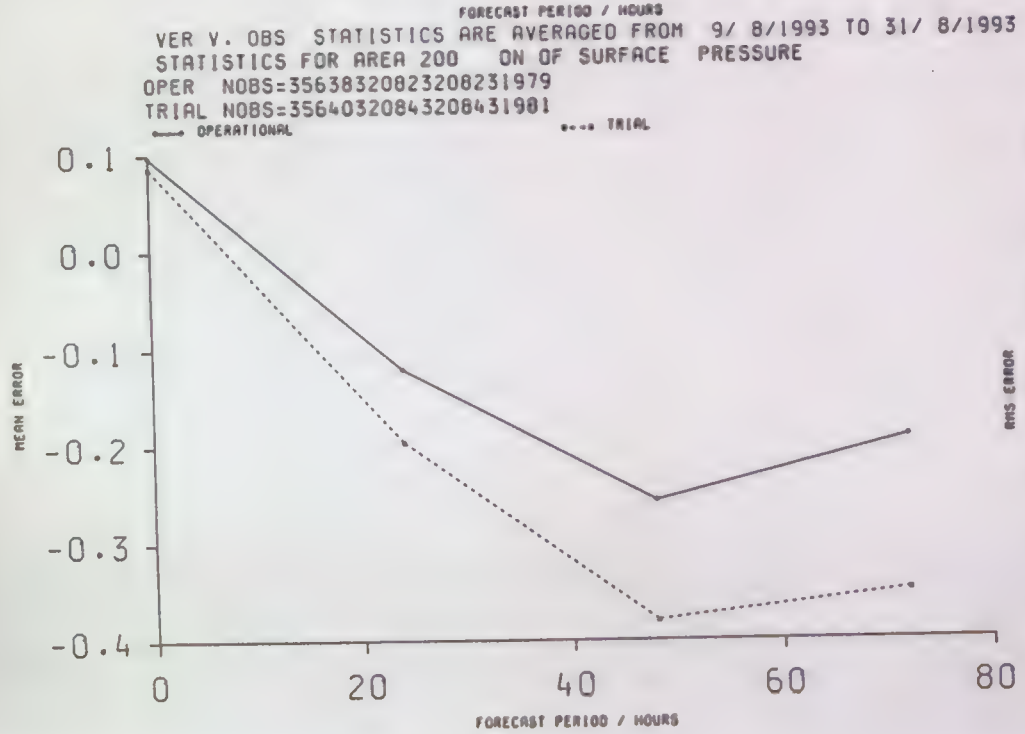


Fig 3.15


VER V. OBS STATISTICS ARE AVERAGED FROM 9/ 8/1993 TO 31/ 8/1993
STATISTICS FOR AREA 2 ON OF SURFACE PRESSURE
OPER NOBS=16929152271522715205
TRIAL NOBS=16932152301523015208
OPERATIONAL
TRIAL
MEAN ERROR
0.2
0.1
0.0
-0.1
-0.2
-0.3
-0.4
-0.5
0
20
40
60
80
FORECAST PERIOD / HOURS


VER V. OBS STATISTICS ARE AVERAGED FROM 9/ 8/1993 TO 31/ 8/1993
STATISTICS FOR AREA 2 ON OF SURFACE PRESSURE
OPER NOBS=16929152271522715205
TRIAL NOBS=16932152301523015208
OPERATIONAL
TRIAL
RMS ERROR
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0
20
40
60
80
FORECAST PERIOD / HOURS


VER V. OBS STATISTICS ARE AVERAGED FROM 9/ 8/1993 TO 31/ 8/1993
STATISTICS FOR AREA 200 ON OF SURFACE PRESSURE
OPER NOBS=35638320823208231979
TRIAL NOBS=35640320843208431981
OPERATIONAL
TRIAL
MEAN ERROR
0.1
0.0
-0.1
-0.2
-0.3
-0.4
0
20
40
60
80
FORECAST PERIOD / HOURS

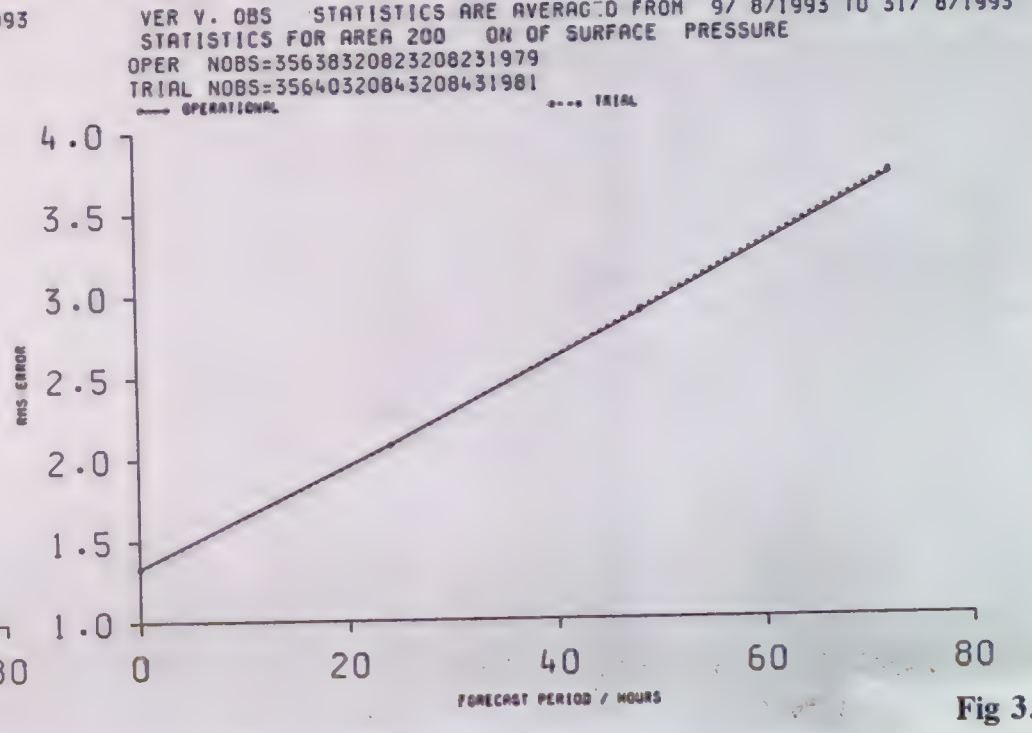
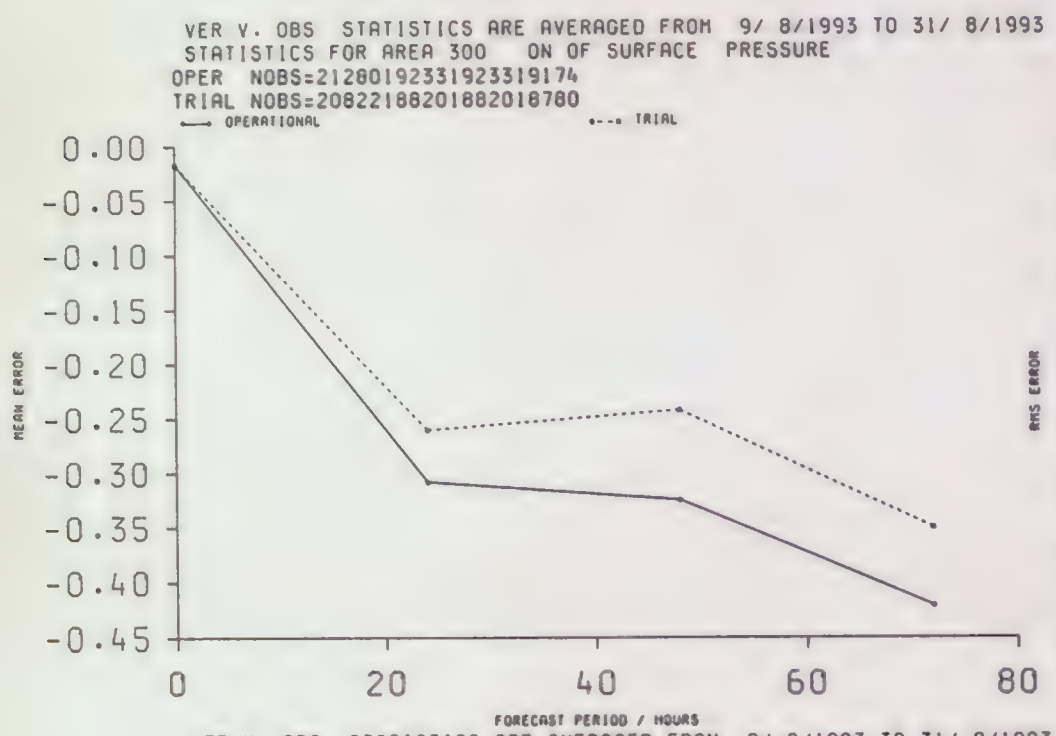
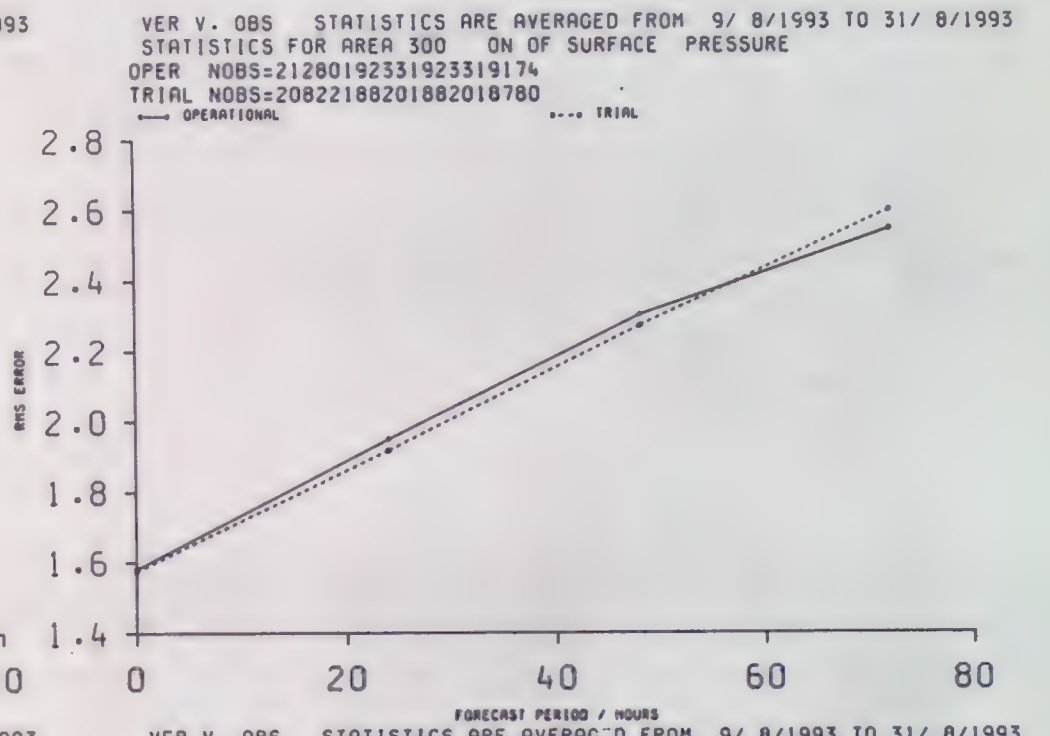
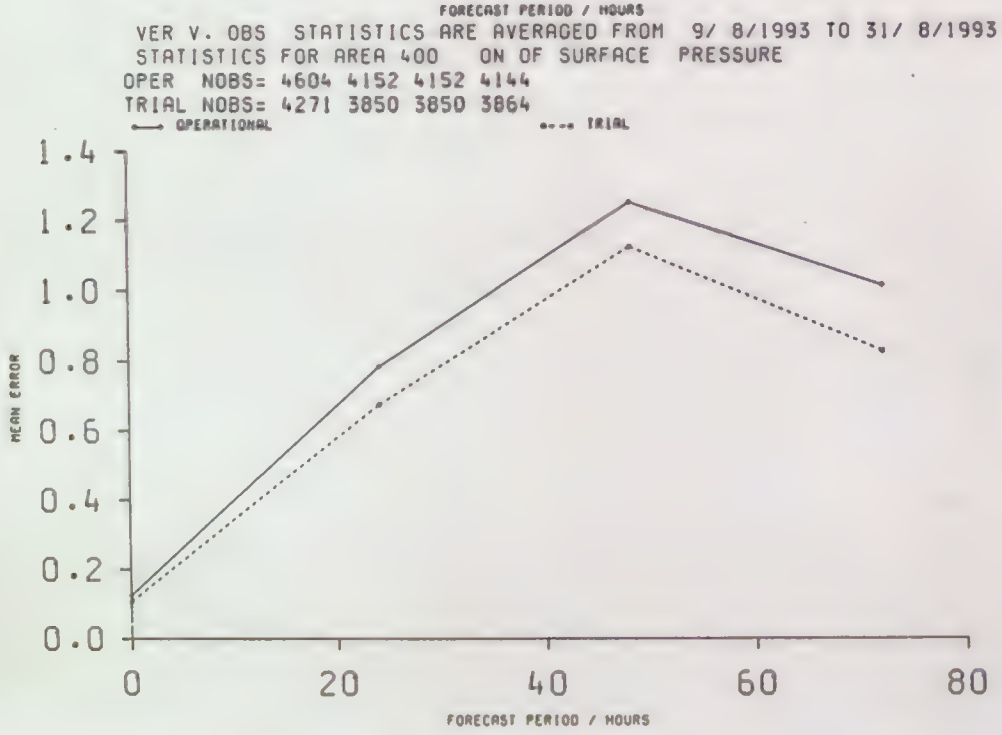

VER V. OBS STATISTICS ARE AVERAGED FROM 9/ 8/1993 TO 31/ 8/1993
STATISTICS FOR AREA 200 ON OF SURFACE PRESSURE
OPER NOBS=35638320823208231979
TRIAL NOBS=35640320843208431981
OPERATIONAL
TRIAL
RMS ERROR
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0
20
40
60
80
FORECAST PERIOD / HOURS

Fig 3.16


VER V. OBS STATISTICS ARE AVERAGED FROM 9/ 8/1993 TO 31/ 8/1993
STATISTICS FOR AREA 300 ON OF SURFACE PRESSURE
OPER NOBS=2128019233192331917 4
TRIAL NOBS=20822188201882018780
OPERATIONAL
TRIAL
MEAN ERROR
0.00
-0.05
-0.10
-0.15
-0.20
-0.25
-0.30
-0.35
-0.40
-0.45
0
20
40
60
80
FORECAST PERIOD / HOURS


VER V. OBS STATISTICS ARE AVERAGED FROM 9/ 8/1993 TO 31/ 8/1993
STATISTICS FOR AREA 300 ON OF SURFACE PRESSURE
OPER NOBS=2128019233192331917 4
TRIAL NOBS=20822188201882018780
OPERATIONAL
TRIAL
RMS ERROR
2.8
2.6
2.4
2.2
2.0
1.8
1.6
1.4
0
20
40
60
80
FORECAST PERIOD / HOURS


VER V. OBS STATISTICS ARE AVERAGED FROM 9/ 8/1993 TO 31/ 8/1993
STATISTICS FOR AREA 400 ON OF SURFACE PRESSURE
OPER NOBS= 4604 4152 4152 4144
TRIAL NOBS= 4271 3850 3850 3864
OPERATIONAL
TRIAL
MEAN ERROR
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0
20
40
60
80
FORECAST PERIOD / HOURS

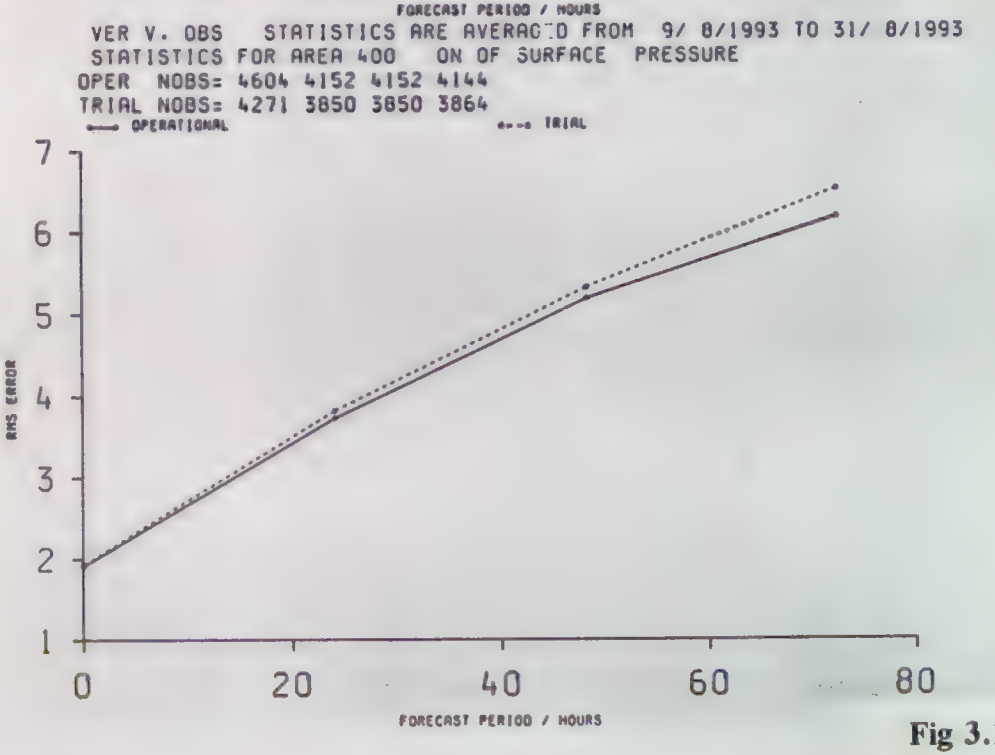

VER V. OBS STATISTICS ARE AVERAGED FROM 9/ 8/1993 TO 31/ 8/1993
STATISTICS FOR AREA 400 ON OF SURFACE PRESSURE
OPER NOBS= 4604 4152 4152 4144
TRIAL NOBS= 4271 3850 3850 3864
OPERATIONAL
TRIAL
RMS ERROR
7
6
5
4
3
2
1
0
20
40
60
80
FORECAST PERIOD / HOURS

Fig 3.17

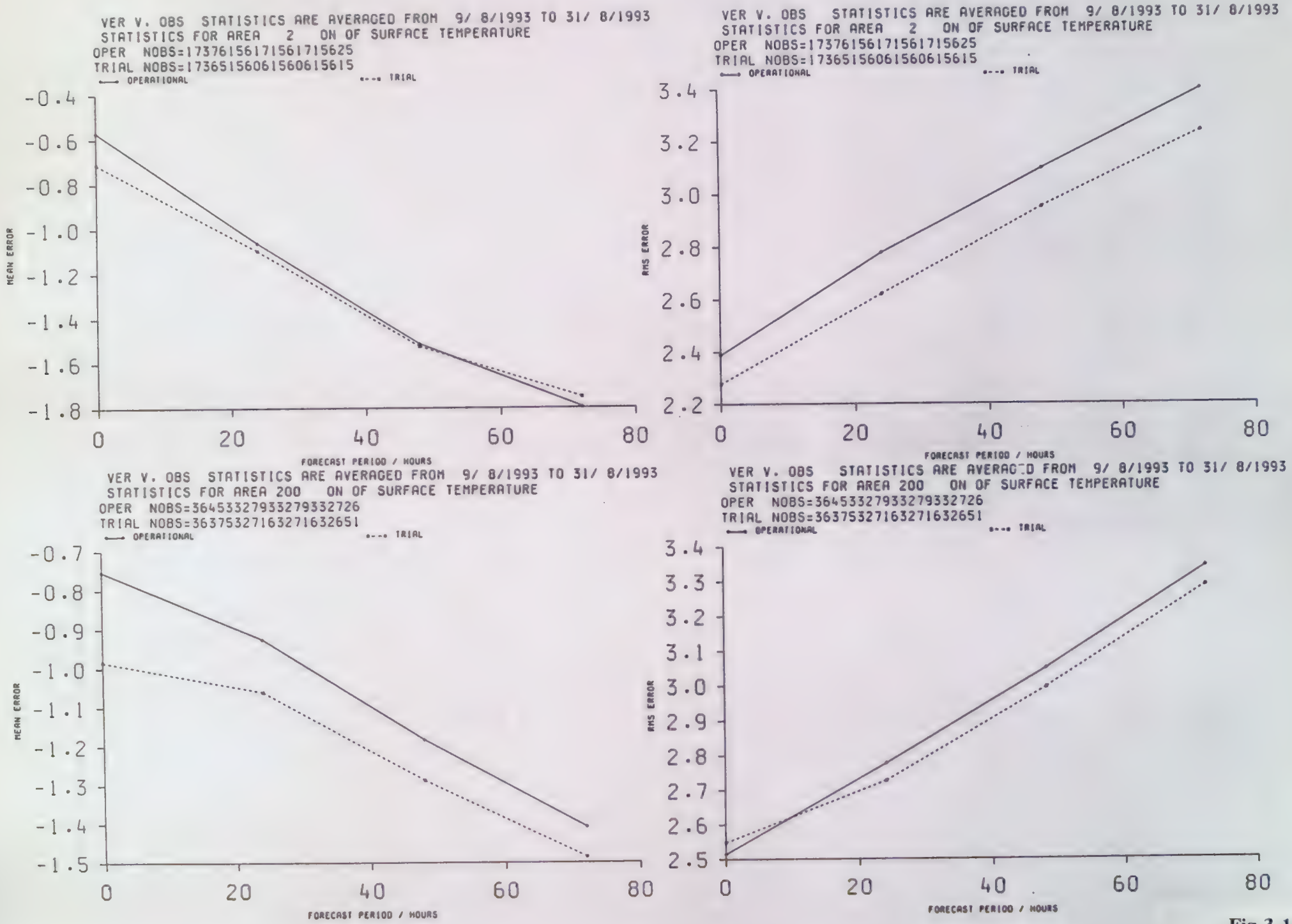

VER V. OBS STATISTICS ARE AVERAGED FROM 9/ 8/1993 TO 31/ 8/1993
STATISTICS FOR AREA 2 ON OF SURFACE TEMPERATURE
OPER NOBS=17376156171561715625
TRIAL NOBS=17365156061560615615
OPERATIONAL
TRIAL
MEAN ERROR
-0.4
-0.6
-0.8
-1.0
-1.2
-1.4
-1.6
-1.8
0
20
40
60
80
FORECAST PERIOD / HOURS
VER V. OBS STATISTICS ARE AVERAGED FROM 9/ 8/1993 TO 31/ 8/1993
STATISTICS FOR AREA 2 ON OF SURFACE TEMPERATURE
OPER NOBS=17376156171561715625
TRIAL NOBS=17365156061560615615
OPERATIONAL
TRIAL
RMS ERROR
3.4
3.2
3.0
2.8
2.6
2.4
2.2
0
20
40
60
80
FORECAST PERIOD / HOURS
VER V. OBS STATISTICS ARE AVERAGED FROM 9/ 8/1993 TO 31/ 8/1993
STATISTICS FOR AREA 200 ON OF SURFACE TEMPERATURE
OPER NOBS=36453327933279332726
TRIAL NOBS=36375327163271632651
OPERATIONAL
TRIAL
MEAN ERROR
-0.7
-0.8
-0.9
-1.0
-1.1
-1.2
-1.3
-1.4
-1.5
0
20
40
60
80
FORECAST PERIOD / HOURS
VER V. OBS STATISTICS ARE AVERAGED FROM 9/ 8/1993 TO 31/ 8/1993
STATISTICS FOR AREA 200 ON OF SURFACE TEMPERATURE
OPER NOBS=36453327933279332726
TRIAL NOBS=36375327163271632651
OPERATIONAL
TRIAL
RMS ERROR
3.4
3.3
3.2
3.1
3.0
2.9
2.8
2.7
2.6
2.5
0
20
40
60
80
FORECAST PERIOD / HOURS

Fig 3.18

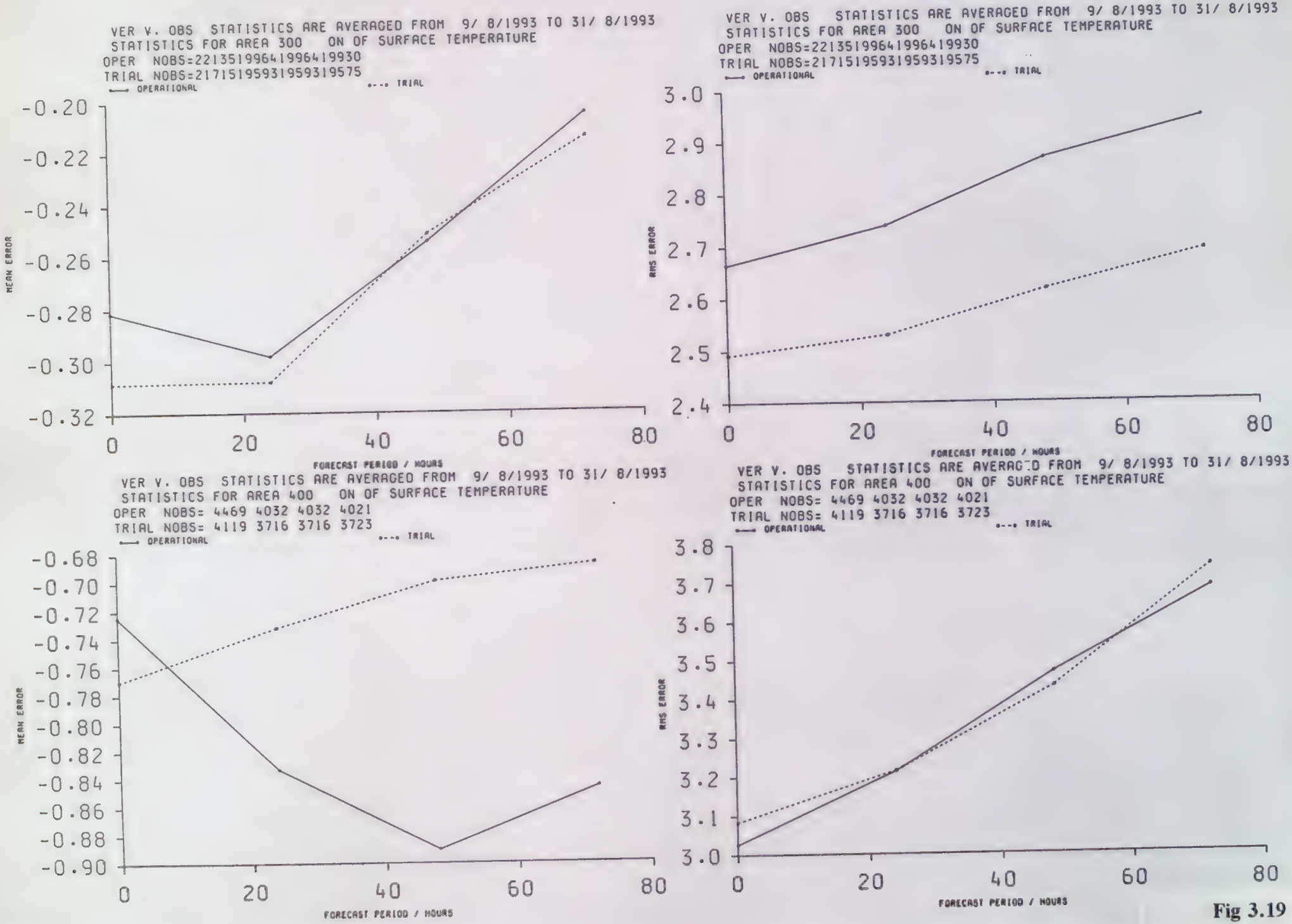

VER V. OBS STATISTICS ARE AVERAGED FROM 9/ 8/1993 TO 31/ 8/1993
STATISTICS FOR AREA 300 ON OF SURFACE TEMPERATURE
OPER NOBS=2213519964199641993O
TRIAL NOBS=21715195931959319575
OPERATIONAL
TRIAL
MEAN ERROR
-0.20
-0.22
-0.24
-0.26
-0.28
-0.30
-0.32
0
20
40
60
80
FORECAST PERIOD / HOURS
VER V. OBS STATISTICS ARE AVERAGED FROM 9/ 8/1993 TO 31/ 8/1993
STATISTICS FOR AREA 300 ON OF SURFACE TEMPERATURE
OPER NOBS=2213519964199641993O
TRIAL NOBS=21715195931959319575
OPERATIONAL
TRIAL
RMS ERROR
3.0
2.9
2.8
2.7
2.6
2.5
2.4
0
20
40
60
80
FORECAST PERIOD / HOURS
VER V. OBS STATISTICS ARE AVERAGED FROM 9/ 8/1993 TO 31/ 8/1993
STATISTICS FOR AREA 400 ON OF SURFACE TEMPERATURE
OPER NOBS= 4469 4032 4032 4021
TRIAL NOBS= 4119 3716 3716 3723
OPERATIONAL
TRIAL
MEAN ERROR
-0.68
-0.70
-0.72
-0.74
-0.76
-0.78
-0.80
-0.82
-0.84
-0.86
-0.88
-0.90
0
20
40
60
80
FORECAST PERIOD / HOURS
VER V. OBS STATISTICS ARE AVERAGED FROM 9/ 8/1993 TO 31/ 8/1993
STATISTICS FOR AREA 400 ON OF SURFACE TEMPERATURE
OPER NOBS= 4469 4032 4032 4021
TRIAL NOBS= 4119 3716 3716 3723
OPERATIONAL
TRIAL
RMS ERROR
3.8
3.7
3.6
3.5
3.4
3.3
3.2
3.1
3.0
0
20
40
60
80
FORECAST PERIOD / HOURS

Fig 3.19

TEMPERATURE %RMS CHANGE (TRIAL-OPERATIONAL)
STATISTICS FOR AREA 2
VERIFICATION AGAINST OBSERVATIONS

	T+0	T+24	T+48	T+72
850	(1.9)	(1.9)	(2.0)	(1.1)
700	(0.5)	(3.2)	(5.5)	(4.2)
500	0.0	1.0	(1.0)	(1.6)
300	(0.5)	1.3	(0.1)	(1.0)
250	(0.8)	(1.1)	(0.8)	0.1
200	0.3	0.8	(0.8)	(0.6)
100	0.0	0.0	(0.8)	(2.1)
50	0.0	1.8	2.4	0.0

TEMPERATURE %RMS CHANGE (TRIAL-OPERATIONAL)
STATISTICS FOR AREA 200
VERIFICATION AGAINST OBSERVATIONS

	T+0	T+24	T+48	T+72
850	(1.1)	(0.9)	(1.9)	(1.3)
700	(0.3)	0.1	(0.1)	(1.1)
500	0.1	0.9	0.7	(0.6)
300	0.0	2.0	2.2	2.0
250	0.1	1.2	1.9	1.6
200	(0.5)	0.2	0.8	0.2
100	(0.1)	0.1	1.2	1.4
50	0.2	(0.6)	(1.0)	(0.1)

TEMPERATURE %RMS CHANGE (TRIAL-OPERATIONAL)
STATISTICS FOR AREA 300
VERIFICATION AGAINST OBSERVATIONS

	T+0	T+24	T+48	T+72
850	(0.9)	1.7	1.3	1.7
700	1.3	1.3	1.5	0.3
500	(1.5)	(1.0)	(1.4)	(0.6)
300	0.5	(0.1)	0.2	(0.5)
250	(0.9)	2.7	3.8	2.8
200	2.2	5.5	7.6	5.5
100	0.0	(0.3)	0.6	0.2
50	0.0	(0.2)	0.2	1.5

TEMPERATURE %RMS CHANGE (TRIAL-OPERATIONAL)
STATISTICS FOR AREA 400
VERIFICATION AGAINST OBSERVATIONS

	T+0	T+24	T+48	T+72
850	0.2	(1.9)	(2.6)	2.0
700	(1.3)	(2.9)	(3.4)	(2.4)
500	(3.1)	0.6	1.5	(1.3)
300	(0.9)	1.6	(0.3)	(1.7)
250	(0.5)	(1.6)	(2.6)	(2.5)
200	(0.9)	0.3	0.0	(0.6)
100	0.3	0.3	0.1	(0.5)
50	0.3	0.5	0.1	0.3

Table 3.1 Percentage change in rms for temperature from verification against observations from trial 2. Reductions in brackets.

TEMP RMSE % CHANGE (TRIAL-OPERATIONAL)
AREA 2
VERIFICATION AGAINST ANALYSES

	T+24	T+48	T+72
850	(1.8)	(2.9)	(2.6)
700	(3.4)	(3.6)	(3.2)
500	(1.2)	(0.7)	(2.6)
300	(0.8)	(1.1)	(0.4)
250	2.2	0.0	(0.4)
200	0.0	(1.4)	(1.5)
100	0.0	0.0	0.0
50	2.8	0.0	(1.7)

TEMP RMSE % CHANGE (TRIAL-OPERATIONAL)
N.HEM
VERIFICATION AGAINST ANALYSES

	T+24	T+48	T+72
850	0.9	(1.2)	(0.9)
700	1.1	(0.7)	(1.6)
500	0.0	0.0	(1.7)
300	0.9	1.8	1.4
250	2.3	1.1	0.8
200	0.8	0.0	0.4
100	0.0	(1.0)	0.7
50	0.0	(2.7)	(2.2)

TEMP RMSE % CHANGE (TRIAL-OPERATIONAL)
TROPICS
VERIFICATION AGAINST ANALYSES

	T+24	T+48	T+72
850	2.7	4.5	5.3
700	0.0	0.8	0.0
500	(3.3)	(4.3)	(2.6)
300	1.4	(0.9)	(1.5)
250	3.7	4.2	4.2
200	7.0	7.5	10.0
100	0.0	(1.0)	(1.8)
50	1.4	1.1	0.9

TEMP RMSE % CHANGE (TRIAL-OPERATIONAL)
S.HEM
VERIFICATION AGAINST ANALYSES

	T+24	T+48	T+72
850	0.6	0.7	0.3
700	0.0	(0.4)	(1.2)
500	(0.7)	(0.4)	(1.7)
300	0.8	0.0	(0.4)
250	1.3	0.5	(0.7)
200	0.0	(0.5)	(1.4)
100	(0.9)	(2.3)	(3.7)
50	(2.2)	(3.7)	(3.1)

Table 3.2 Percentage change in rms for temperature from verification against analyses from trial 2. Reductions in brackets.

HEIGHT %RMS CHANGE (TRIAL-OPERATIONAL)
STATISTICS FOR AREA 2
VERIFICATION AGAINST OBSERVATIONS

	T+0	T+24	T+48	T+72
850	0.6	(0.4)	(0.9)	0.2
700	(0.5)	(0.1)	(0.6)	(2.2)
500	0.8	0.3	(1.6)	(2.7)
300	0.3	0.8	(2.4)	(2.7)
250	0.3	1.6	(2.2)	(3.2)
200	(0.1)	1.4	(2.5)	(3.6)
100	0.2	1.3	(1.4)	(2.6)
50	(0.1)	1.1	(0.1)	(0.9)

HEIGHT %RMS CHANGE (TRIAL-OPERATIONAL)
STATISTICS FOR AREA 200
VERIFICATION AGAINST OBSERVATIONS

	T+0	T+24	T+48	T+72
850	0.7	(0.4)	1.3	0.5
700	0.1	0.2	1.0	0.6
500	0.6	0.2	(0.3)	(0.3)
300	0.3	0.9	(0.2)	(0.2)
250	0.6	1.3	0.1	(0.2)
200	0.4	1.8	0.8	0.2
100	(0.1)	0.5	(0.5)	(1.6)
50	(0.2)	0.0	(1.6)	(2.3)

HEIGHT %RMS CHANGE (TRIAL-OPERATIONAL)
STATISTICS FOR AREA 300
VERIFICATION AGAINST OBSERVATIONS

	T+0	T+24	T+48	T+72
850	(0.8)	(0.3)	2.0	6.6
700	(0.1)	2.1	4.9	8.6
500	(0.1)	0.7	0.9	2.7
300	0.3	0.8	(0.3)	(0.3)
250	0.1	0.6	(0.4)	(0.7)
200	1.2	2.4	2.0	2.0
100	0.1	0.2	(1.3)	(1.8)
50	(0.1)	0.4	(1.2)	(1.8)

HEIGHT %RMS CHANGE (TRIAL-OPERATIONAL)
STATISTICS FOR AREA 400
VERIFICATION AGAINST OBSERVATIONS

	T+0	T+24	T+48	T+72
850	1.2	1.1	1.8	3.4
700	(0.4)	0.2	1.4	1.8
500	(0.3)	(0.2)	0.7	0.3
300	(2.1)	0.6	1.8	1.8
250	0.6	1.9	2.4	2.1
200	0.0	1.7	1.9	2.3
100	0.0	0.0	(2.0)	(1.0)
50	0.1	(0.4)	(1.6)	(2.7)

Table 3.3 Percentage change in rms for height from verification against observations from trial 2. Reductions in brackets.

HEIGHT RMSE % CHANGE (TRIAL-OPERATIONAL)
AREA 5
VERIFICATION AGAINST ANALYSES

	T+24	T+48	T+72
850	(1.7)	(1.0)	(0.7)
700	0.0	0.5	(1.0)
500	0.0	(0.4)	(1.5)
300	(1.4)	(1.5)	(1.8)
250	(1.3)	(1.6)	(1.7)
200	(0.9)	(1.7)	(1.9)
100	0.0	(1.8)	(2.7)
50	0.5	(1.0)	(2.6)

HEIGHT RMSE % CHANGE (TRIAL-OPERATIONAL)
N.HEM
VERIFICATION AGAINST ANALYSES

	T+24	T+48	T+72
850	(0.8)	(1.0)	(0.4)
700	(0.8)	(0.5)	0.0
500	0.0	(0.4)	(0.3)
300	0.0	(0.3)	0.2
250	0.0	(0.5)	0.2
200	0.9	0.0	0.4
100	1.0	(1.7)	(2.1)
50	(0.4)	(4.0)	(4.4)

HEIGHT RMSE % CHANGE (TRIAL-OPERATIONAL)
TROPICS
VERIFICATION AGAINST ANALYSES

	T+24	T+48	T+72
850	(1.1)	(0.9)	5.3
700	3.7	0.0	6.9
500	2.5	0.0	2.2
300	1.0	(2.0)	(2.6)
250	1.7	(1.7)	(2.6)
200	2.9	0.0	(1.1)
100	1.2	(2.4)	(3.8)
50	0.0	(3.0)	(5.0)

HEIGHT RMSE % CHANGE (TRIAL-OPERATIONAL)
S.HEM
VERIFICATION AGAINST ANALYSES

	T+24	T+48	T+72
850	0.0	(0.8)	0.6
700	(0.5)	(0.8)	0.2
500	(1.1)	(0.9)	(0.5)
300	(0.9)	(0.8)	(1.3)
250	(0.6)	(1.2)	(1.5)
200	(0.3)	(1.8)	(2.0)
100	(0.7)	(3.3)	(3.9)
50	(2.0)	(4.1)	(5.9)

Table 3.4 Percentage change in rms for height from verification against analyses from trial 2. Reductions in brackets.

WIND %RMS CHANGE (TRIAL-OPERATIONAL)
STATISTICS FOR AREA 2
VERIFICATION AGAINST OBSERVATIONS

	T+0	T+24	T+48	T+72
850	0.3	(0.5)	(0.3)	(1.2)
700	(0.3)	(0.4)	(1.0)	(0.9)
500	0.1	(0.2)	(1.4)	(1.0)
400	0.2	(0.2)	(1.3)	(1.3)
300	0.0	0.0	(1.1)	(1.5)
250	0.2	(0.1)	(1.4)	(1.2)
200	0.0	(1.2)	(1.8)	(1.6)
100	0.0	(0.9)	(2.8)	(2.2)

WIND %RMS CHANGE (TRIAL-OPERATIONAL)
STATISTICS FOR AREA 200
VERIFICATION AGAINST OBSERVATIONS

	T+0	T+24	T+48	T+72
850	0.0	(0.8)	0.1	0.4
700	0.2	(0.5)	0.4	0.8
500	0.1	0.0	0.3	0.9
400	0.0	0.1	0.4	0.7
300	0.1	0.4	0.5	1.0
250	0.2	0.5	1.1	1.6
200	0.2	(0.9)	1.6	2.6
100	(0.2)	(1.2)	(1.1)	0.0

WIND %RMS CHANGE (TRIAL-OPERATIONAL)
STATISTICS FOR AREA 300
VERIFICATION AGAINST OBSERVATIONS

	T+0	T+24	T+48	T+72
850	(0.4)	(0.8)	1.8	1.0
700	(0.2)	0.5	3.5	4.2
500	(0.4)	0.3	2.2	2.2
400	0.3	(0.1)	2.0	1.3
300	(0.4)	0.4	0.6	(1.9)
250	(0.2)	(1.0)	(1.2)	(1.7)
200	1.0	(0.5)	(0.8)	(1.0)
100	0.5	(0.4)	(0.9)	(0.5)

WIND %RMS CHANGE (TRIAL-OPERATIONAL)
STATISTICS FOR AREA 400
VERIFICATION AGAINST OBSERVATIONS

	T+0	T+24	T+48	T+72
850	(0.8)	(0.9)	0.1	1.9
700	(0.5)	0.2	0.6	1.9
500	0.2	(0.5)	(0.8)	(0.7)
400	(1.2)	(0.3)	(0.5)	1.1
300	(0.5)	(0.9)	(1.8)	(0.3)
250	(0.7)	(1.5)	(2.0)	(1.1)
200	(1.3)	(2.4)	(4.3)	(2.2)
100	(0.5)	(0.1)	0.7	0.2

Table 3.5 Percentage change in rms for winds from verification against observations from trial 2. Reductions in brackets.

WIND RMSVW % CHANGE (TRIAL-OPERATIONAL)
AREA 2
VERIFICATION AGAINST ANALYSES

	T+24	T+48	T+72
850	(1.3)	0.1	0.1
700	(0.4)	0.5	0.0
500	(0.3)	(0.4)	(0.6)
300	(0.2)	(0.7)	(1.9)
250	(0.1)	(0.6)	(1.6)
200	0.3	0.1	(1.4)
100	(0.9)	(0.8)	0.1

WIND RMSVW % CHANGE (TRIAL-OPERATIONAL)
N.HEM
VERIFICATION AGAINST ANALYSES

	T+24	T+48	T+72
850	(0.2)	0.7	1.0
700	(0.4)	0.4	0.9
500	(0.3)	0.1	0.7
300	0.3	0.8	1.0
250	0.1	1.0	1.8
200	(0.5)	1.7	3.0
100	(0.4)	0.1	1.6

WIND RMSVW % CHANGE (TRIAL-OPERATIONAL)
TROPICS
VERIFICATION AGAINST ANALYSES

	T+24	T+48	T+72
850	(1.1)	0.5	1.9
700	1.7	3.1	4.0
500	(0.4)	(0.4)	1.0
300	0.4	1.0	0.3
250	0.1	0.9	(0.1)
200	0.0	(0.8)	(0.9)
100	0.0	(0.4)	(0.5)

WIND RMSVW % CHANGE (TRIAL-OPERATIONAL)
S.HEM
VERIFICATION AGAINST ANALYSES

	T+24	T+48	T+72
850	(0.3)	0.3	0.2
700	(0.7)	(0.3)	(0.2)
500	(0.6)	(0.3)	(0.3)
300	0.0	0.0	(0.4)
250	0.1	(0.4)	(1.2)
200	0.1	(0.8)	(1.4)
100	0.0	(1.4)	(1.9)

Table 3.6 Percentage change in rms for winds from verification against analyses from trial 2. Reductions in brackets.

REL HUM %RMS CHANGE (TRIAL-OPERATIONAL)
STATISTICS FOR AREA 2
VERIFICATION AGAINST OBSERVATIONS

	T+0	T+24	T+48	T+72
850	(0.4)	(0.5)	(0.8)	(0.5)
700	(1.3)	(3.4)	(4.2)	(4.6)
500	(1.0)	(0.4)	(0.3)	0.4

REL HUM %RMS CHANGE (TRIAL-OPERATIONAL)
STATISTICS FOR AREA 200
VERIFICATION AGAINST OBSERVATIONS

	T+0	T+24	T+48	T+72
850	0.0	(0.5)	(0.4)	0.5
700	(0.9)	(2.5)	(2.2)	(1.4)
500	(0.4)	(0.8)	0.4	0.8

REL HUM %RMS CHANGE (TRIAL-OPERATIONAL)
STATISTICS FOR AREA 300
VERIFICATION AGAINST OBSERVATIONS

	T+0	T+24	T+48	T+72
850	(0.6)	0.1	2.7	3.3
700	(1.2)	(0.3)	0.0	1.4
500	(0.7)	(1.4)	(1.4)	(1.6)

REL HUM %RMS CHANGE (TRIAL-OPERATIONAL)
STATISTICS FOR AREA 400
VERIFICATION AGAINST OBSERVATIONS

	T+0	T+24	T+48	T+72
850	1.3	1.3	3.7	3.9
700	2.0	0.6	5.6	2.3
500	0.7	1.1	0.7	1.7

Table 3.7 Percentage change in rms for relative humidity from verification against observations from trial 2. Reductions in brackets.

RELHUM RMSE % CHANGE (TRIAL-OPERATIONAL)
AREA 2
VERIFICATION AGAINST ANALYSES

	T+24	T+48	T+72
950	7.0	6.0	3.4
850	0.3	0.9	0.6
700	(1.3)	1.3	(0.2)
500	0.8	0.8	1.6

RELHUM RMSE % CHANGE (TRIAL-OPERATIONAL)
N.HEM
VERIFICATION AGAINST ANALYSES

	T+24	T+48	T+72
950	2.9	2.0	1.3
850	0.5	0.9	1.8
700	(1.0)	0.8	1.0
500	0.6	1.3	1.5

RELHUM RMSE % CHANGE (TRIAL-OPERATIONAL)
TROPICS
VERIFICATION AGAINST ANALYSES

	T+24	T+48	T+72
950	8.5	6.0	3.0
850	9.5	12.7	12.6
700	1.1	2.1	3.2
500	(3.8)	(4.6)	(4.5)

RELHUM RMSE % CHANGE (TRIAL-OPERATIONAL)
S.HEM
VERIFICATION AGAINST ANALYSES

	T+24	T+48	T+72
950	0.4	(0.1)	(2.1)
850	2.0	2.3	2.6
700	(2.7)	(0.9)	0.3
500	1.2	0.9	0.8

Table 3.8 Percentage change in rms for relative humidity from verification against analyses from trial 2. Reductions in brackets.

Table 3.9 Count of cases in which trial rms is better than or equal to the operational rms from verification against observations and against analyses from trial 2.

RMS RATIO (TRIAL/OPERATIONAL) ≤ 100%
FOR ALL TIMES AND ALL LEVELS
VERIFICATION AGAINST OBSERVATIONS

	TEMP max=32	HEIGHT max=32	WIND max=32	REL HUM max=12
AREA 2	25	20	19	11
N HEM	14	13	10	9
TROPICS	12	13	17	8
S HEM	19	12	23	0

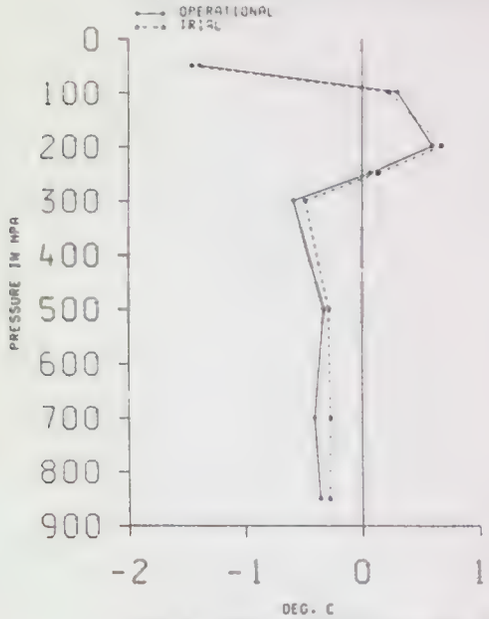
max=no.times x no. levels
Second frozen physics trial

RMS RATIO (TRIAL/OPERATIONAL) ≤ 100%
FOR ALL TIMES AND ALL LEVELS
VERIFICATION AGAINST ANALYSES

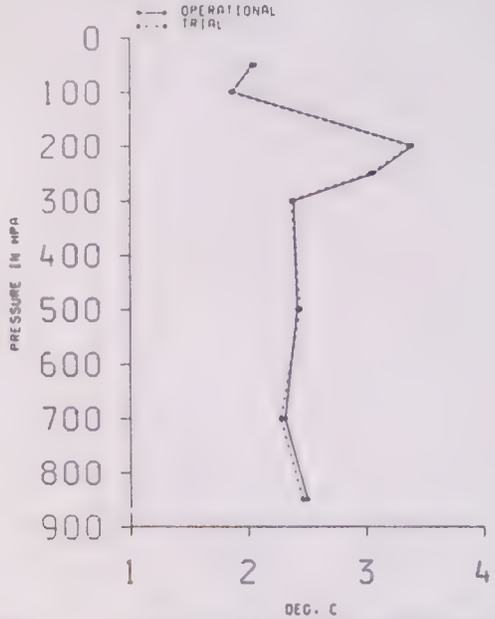
	TEMP max=24	HEIGHT max=24	WIND max=21	REL HUM max=12
AREA 2	22	22	15	2
N HEM	13	19	5	1
TROPICS	10	15	10	3
S HEM	18	22	17	4

max=no.times x no. levels
Second frozen physics trial

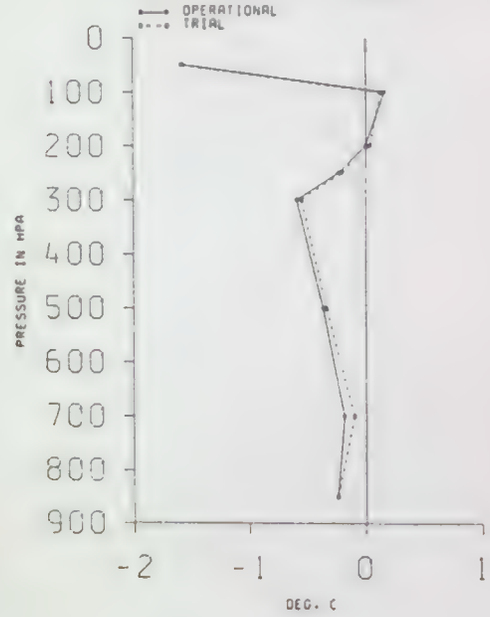
VER V. OBS STATISTICS ARE AVERAGED FROM 10/ 9/1993 TO 28/ 9/1993
MEAN STATISTICS FOR AREA 2 TEMPERATURET+72
OPER NOBS= 2282 2275 2265 2241 2235 2215 2137 1694
TRIAL NOBS= 2282 2275 2265 2241 2235 2215 2137 1694



VER V. OBS STATISTICS ARE AVERAGED FROM 10/ 9/1993 TO 28/ 9/1993
RMS STATISTICS FOR AREA 2 TEMPERATURET+72



VER V. OBS STATISTICS ARE AVERAGED FROM 10/ 9/1993 TO 28/ 9/1993
MEAN STATISTICS FOR AREA 200 TEMPERATURET+72
OPER NOBS= 5743 5934 5977 5878 5828 5795 5490 4393
TRIAL NOBS= 5745 5934 5977 5878 5829 5795 5490 4393



VER V. OBS STATISTICS ARE AVERAGED FROM 10/ 9/1993 TO 28/ 9/1993
RMS STATISTICS FOR AREA 200 TEMPERATURET+72

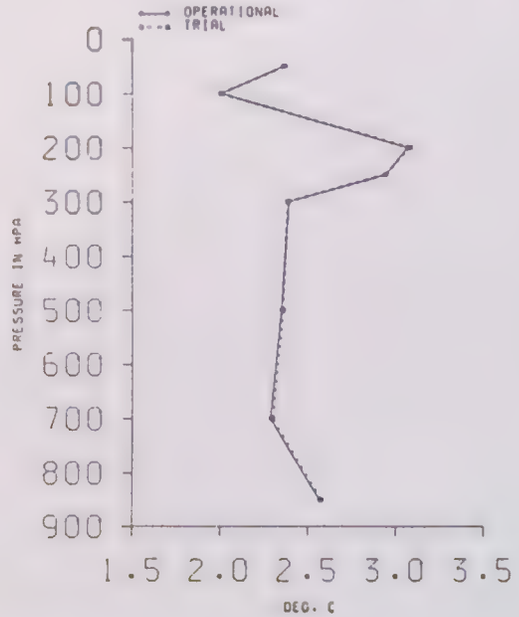
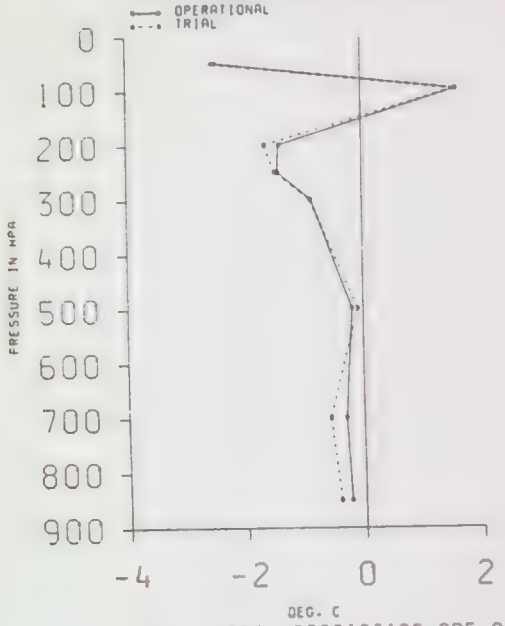
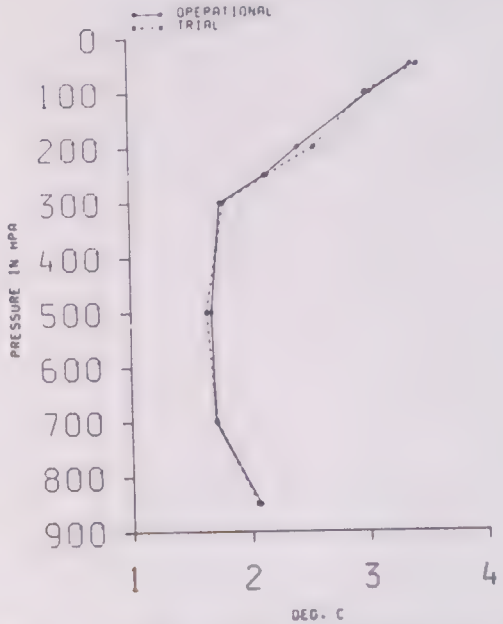


Fig 4.01

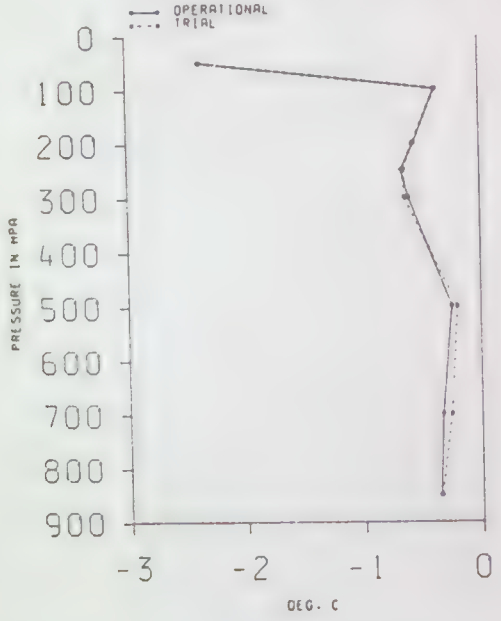
VER V. OBS STATISTICS ARE AVERAGED FROM 10/ 9/1993 TO 28/ 9/1993
MEAN STATISTICS FOR AREA 300 TEMPERATURE+72
OPER NOBS= 2225 2351 2349 2269 2223 2256 2090 1551
TRIAL NOBS= 2223 2352 2353 2272 2227 2256 2090 1553



VER V. OBS STATISTICS ARE AVERAGED FROM 10/ 9/1993 TO 28/ 9/1993
RMS STATISTICS FOR AREA 300 TEMPERATURE+72



VER V. OBS STATISTICS ARE AVERAGED FROM 10/ 9/1993 TO 28/ 9/1993
MEAN STATISTICS FOR AREA 400 TEMPERATURE+72
OPER NOBS= 455 456 457 452 451 453 429 340
TRIAL NOBS= 455 456 457 452 451 453 429 340



VER V. OBS STATISTICS ARE AVERAGED FROM 10/ 9/1993 TO 28/ 9/1993
RMS STATISTICS FOR AREA 400 TEMPERATURE+72

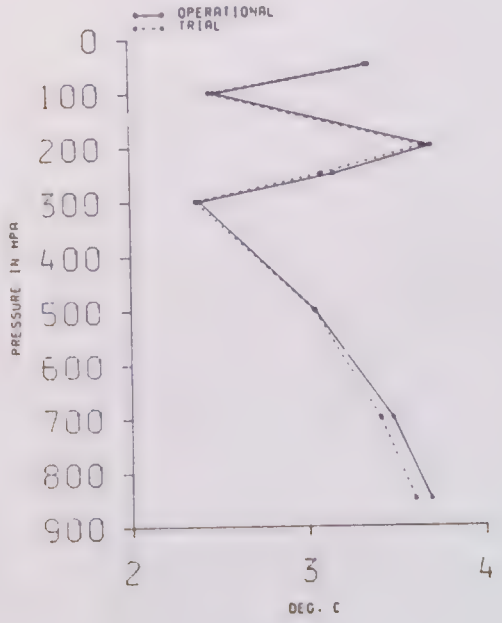
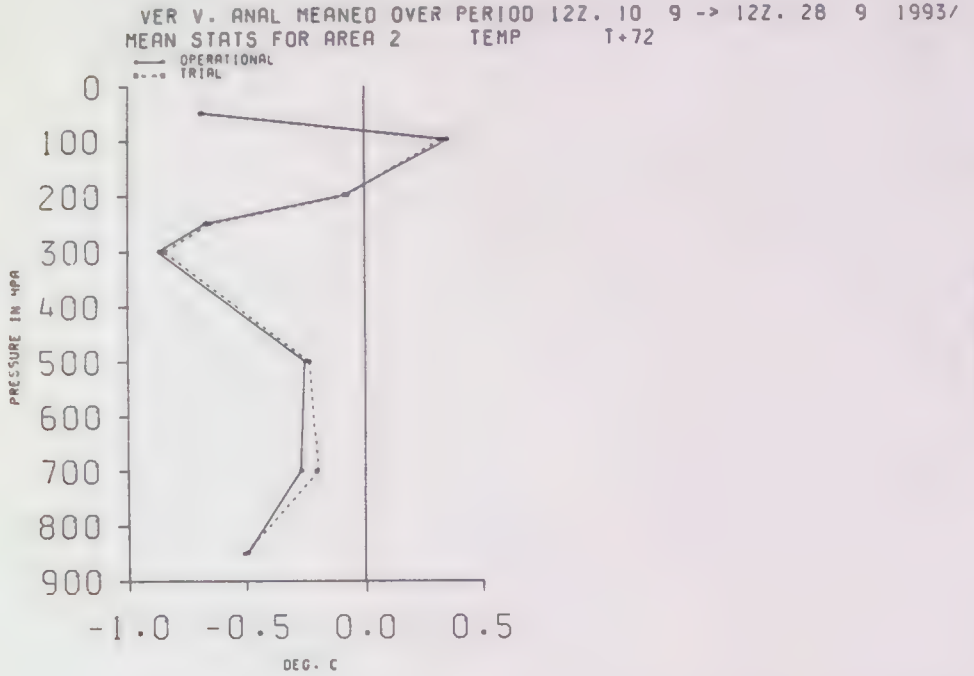
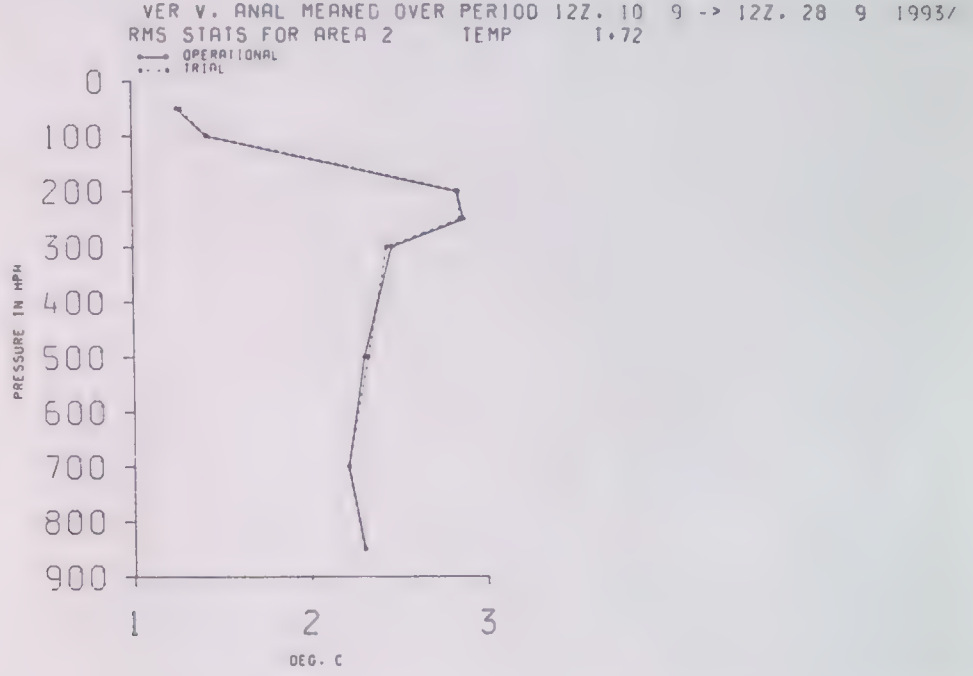
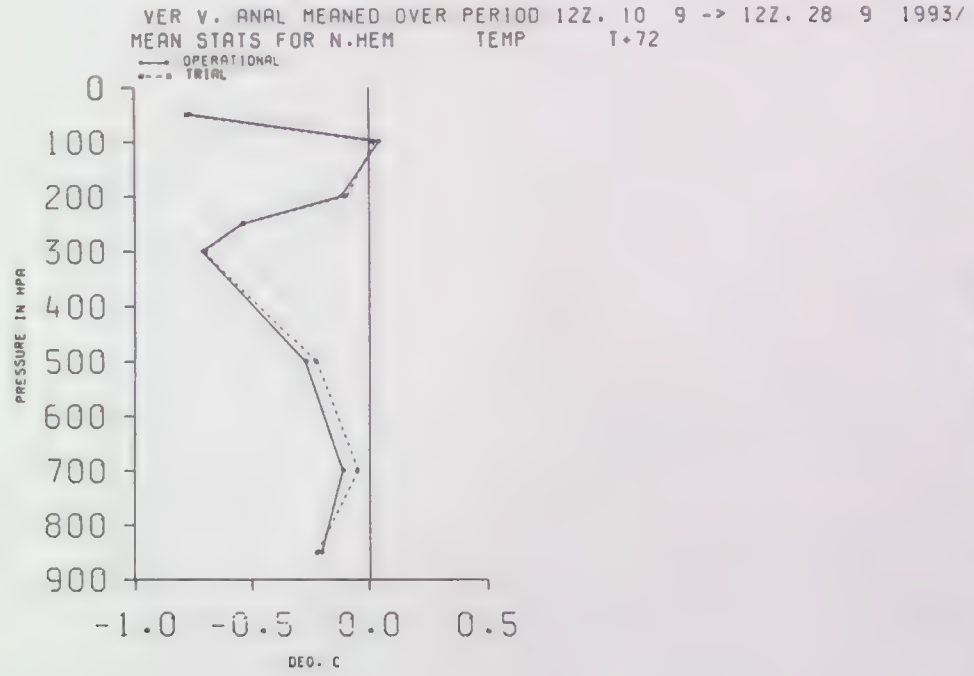


Fig 4.02


VER V. ANAL MEANED OVER PERIOD 12Z. 10 9 -> 12Z. 28 9 1993/
MEAN STATS FOR AREA 2 TEMP T+72
OPERATIONAL
TRIAL
PRESSURE IN HPA
0
100
200
300
400
500
600
700
800
900
-1.0 -0.5 0.0 0.5
DEG. C


VER V. ANAL MEANED OVER PERIOD 12Z. 10 9 -> 12Z. 28 9 1993/
RMS STATS FOR AREA 2 TEMP T+72
OPERATIONAL
TRIAL
PRESSURE IN HPA
0
100
200
300
400
500
600
700
800
900
1 2 3
DEG. C


VER V. ANAL MEANED OVER PERIOD 12Z. 10 9 -> 12Z. 28 9 1993/
MEAN STATS FOR N.HEM TEMP T+72
OPERATIONAL
TRIAL
PRESSURE IN HPA
0
100
200
300
400
500
600
700
800
900
-1.0 -0.5 0.0 0.5
DEG. C

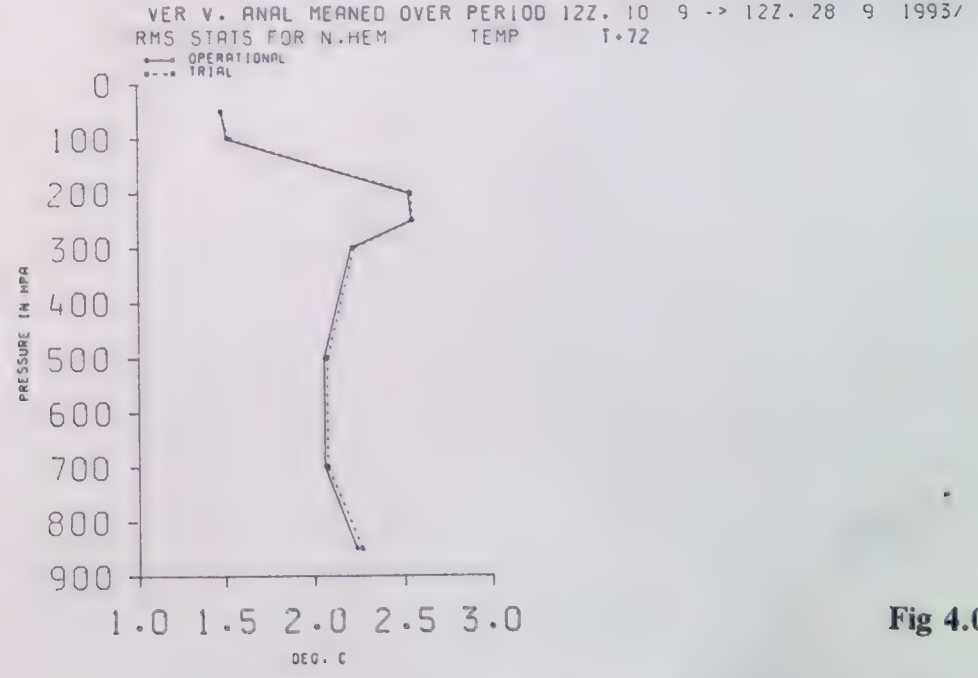
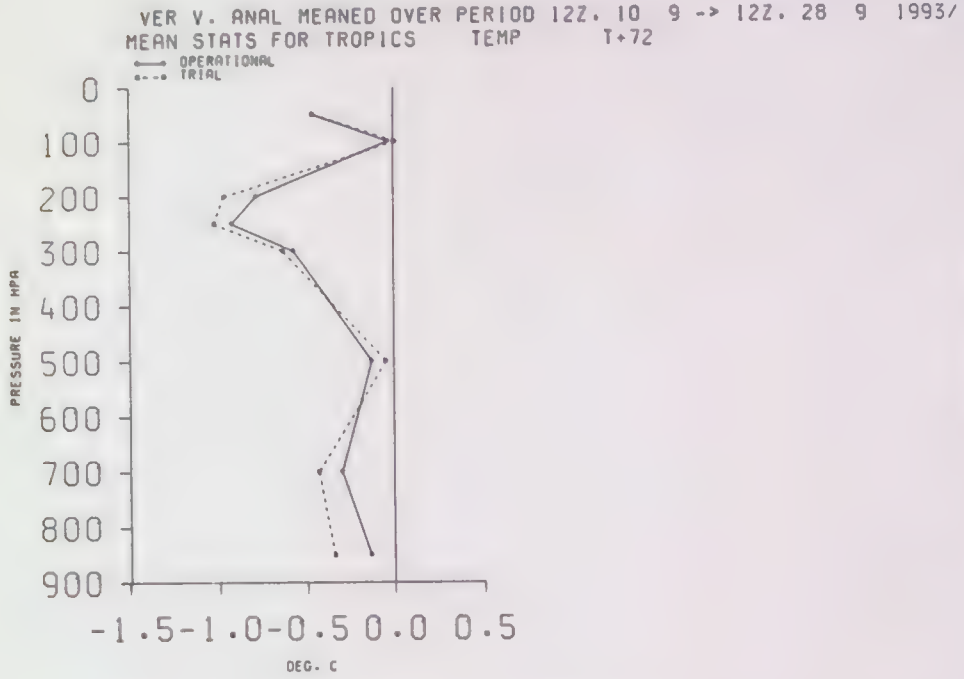
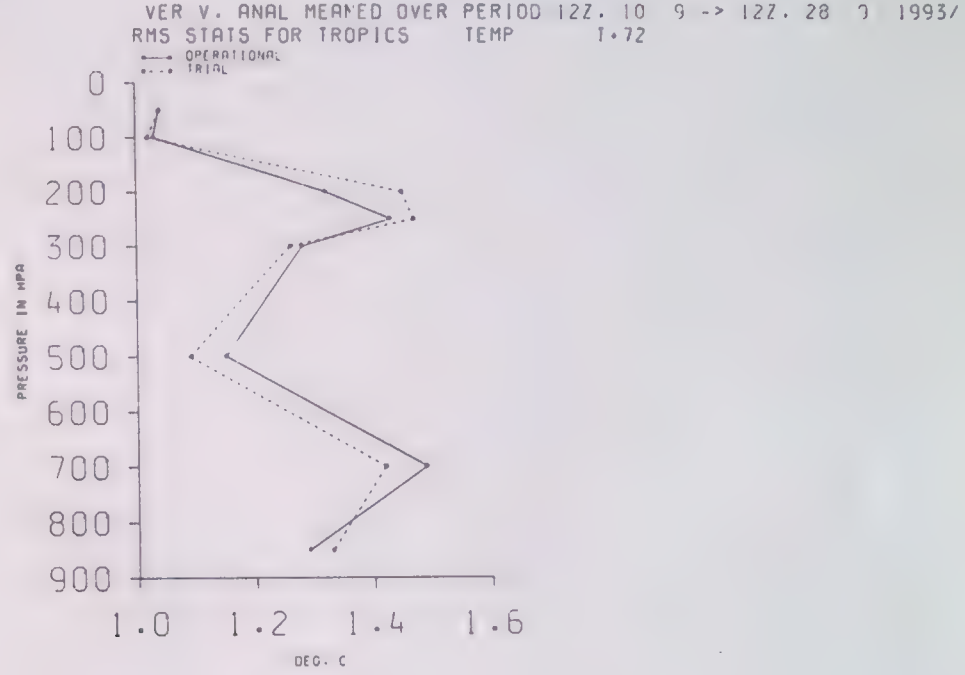
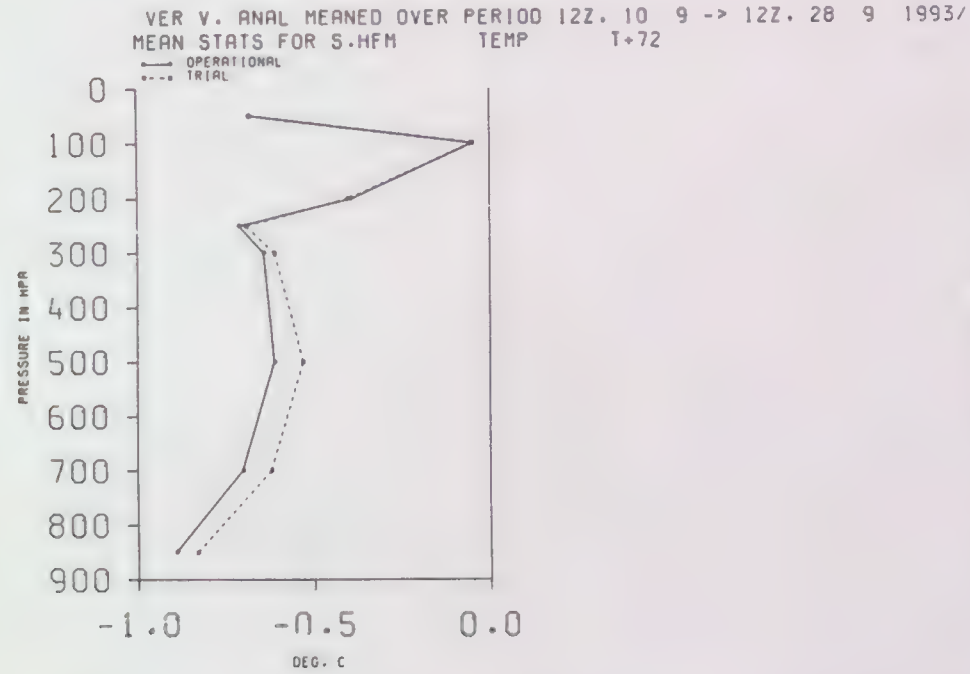

VER V. ANAL MEANED OVER PERIOD 12Z. 10 9 -> 12Z. 28 9 1993/
RMS STATS FOR N.HEM TEMP T+72
OPERATIONAL
TRIAL
PRESSURE IN HPA
0
100
200
300
400
500
600
700
800
900
1.0 1.5 2.0 2.5 3.0
DEG. C

Fig 4.03


VER V. ANAL MEANED OVER PERIOD 12Z. 10 9 -> 12Z. 28 9 1993/
MEAN STATS FOR TROPICS TEMP T+72
OPERATIONAL
TRIAL
PRESSURE IN MPA
0
100
200
300
400
500
600
700
800
900
-1.5 -1.0 -0.5 0.0 0.5
DEG. C


VER V. ANAL MEANED OVER PERIOD 12Z. 10 9 -> 12Z. 28 9 1993/
RMS STATS FOR TROPICS TEMP T+72
OPERATIONAL
TRIAL
PRESSURE IN MPA
0
100
200
300
400
500
600
700
800
900
1.0 1.2 1.4 1.6
DEG. C


VER V. ANAL MEANED OVER PERIOD 12Z. 10 9 -> 12Z. 28 9 1993/
MEAN STATS FOR S.HEM TEMP T+72
OPERATIONAL
TRIAL
PRESSURE IN MPA
0
100
200
300
400
500
600
700
800
900
-1.0 -0.5 0.0
DEG. C

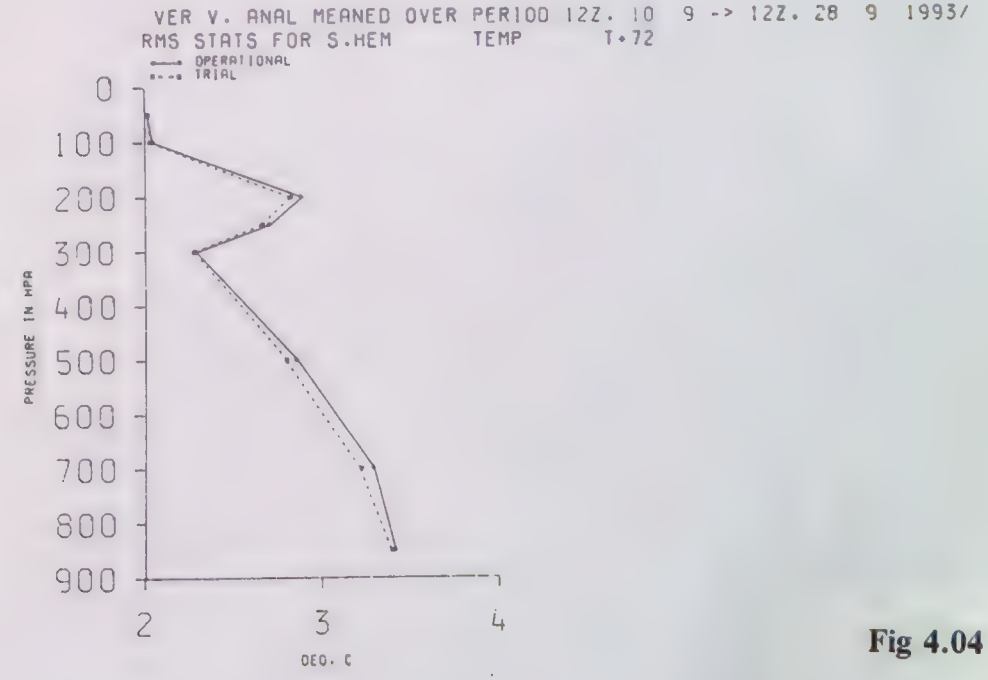
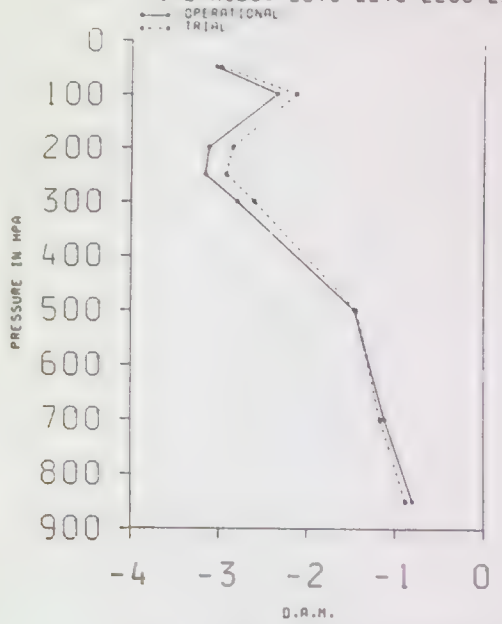
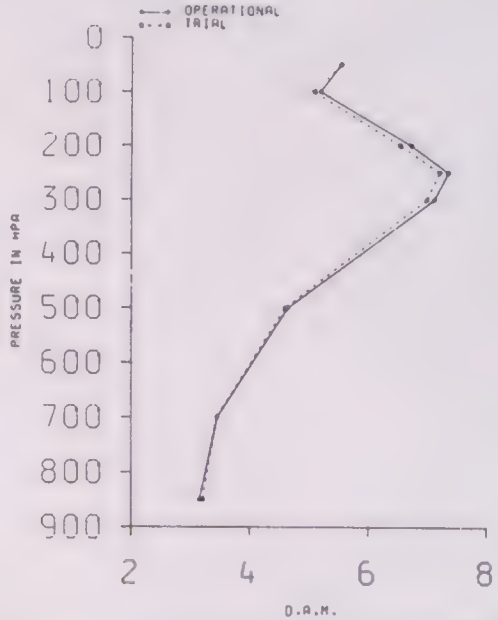

VER V. ANAL MEANED OVER PERIOD 12Z. 10 9 -> 12Z. 28 9 1993/
RMS STATS FOR S.HEM TEMP T+72
OPERATIONAL
TRIAL
PRESSURE IN MPA
0
100
200
300
400
500
600
700
800
900
2 3 4
DEG. C

Fig 4.04

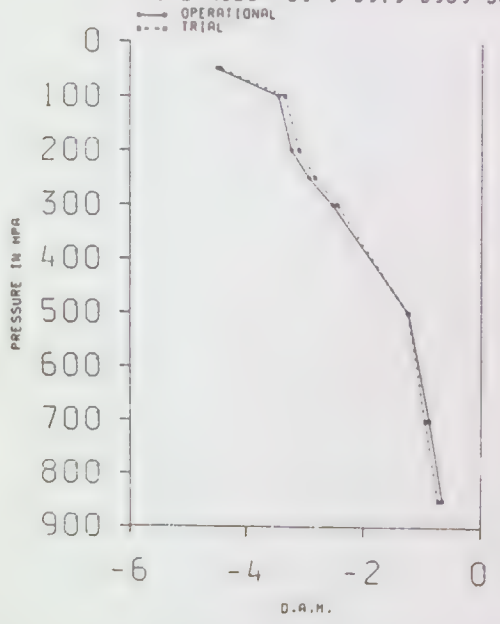
VER V. OBS STATISTICS ARE AVERAGED FROM 10/ 9/1993 TO 28/ 9/1993
MEAN STATISTICS FOR AREA 2 HEIGHT T+72
OPER NOBS= 2275 2270 2268 2238 2235 2216 2146 1731
TRIAL NOBS= 2275 2270 2268 2238 2235 2216 2146 1732



VER V. OBS STATISTICS ARE AVERAGED FROM 10/ 9/1993 TO 28/ 9/1993
RMS STATISTICS FOR AREA 2 HEIGHT T+72



VER V. OBS STATISTICS ARE AVERAGED FROM 10/ 9/1993 TO 28/ 9/1993
MEAN STATISTICS FOR AREA 200 HEIGHT T+72
OPER NOBS= 5949 5918 5989 5880 5829 5789 5459 4376
TRIAL NOBS= 5949 5919 5989 5880 5830 5789 5458 4377



VER V. OBS STATISTICS ARE AVERAGED FROM 10/ 9/1993 TO 28/ 9/1993
RMS STATISTICS FOR AREA 200 HEIGHT T+72

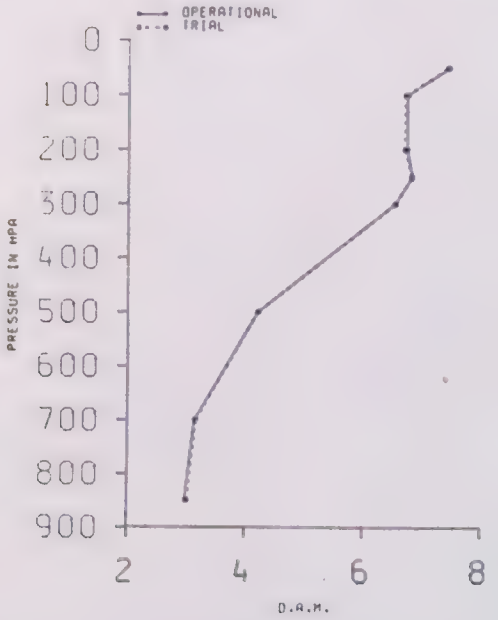
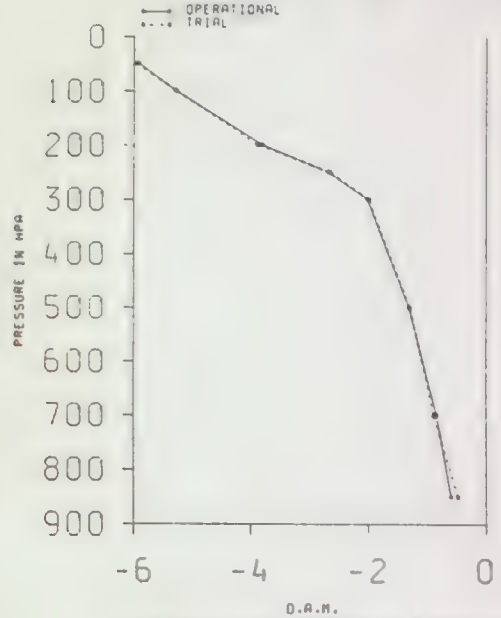
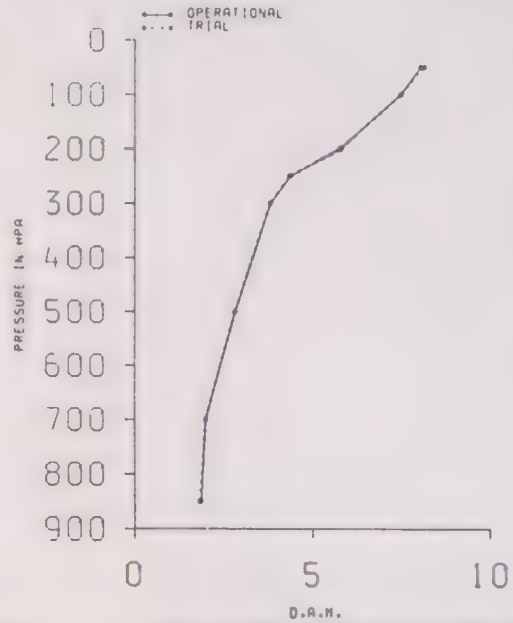


Fig 4.05

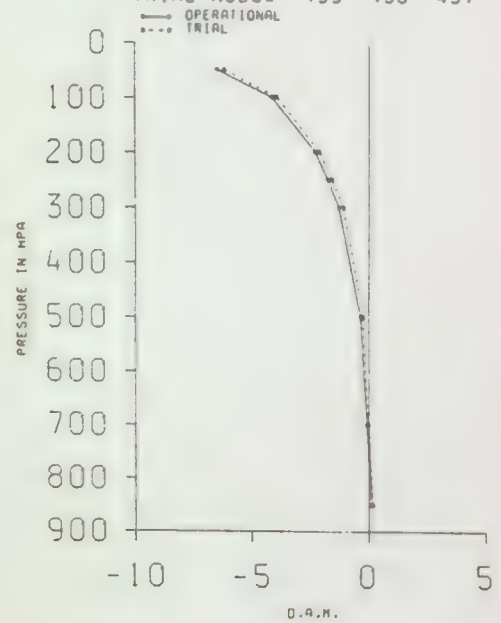
VER V. OBS STATISTICS ARE AVERAGED FROM 10/ 9/1993 TO 28/ 9/1993
MEAN STATISTICS FOR AREA 300 HEIGHT T+72
OPER NOBS= 2399 2371 2394 2260 2177 2212 2025 1501
TRIAL NOBS= 2399 2369 2393 2260 2178 2212 2025 1501



VER V. OBS STATISTICS ARE AVERAGED FROM 10/ 9/1993 TO 28/ 9/1993
RMS STATISTICS FOR AREA 300 HEIGHT T+72



VER V. OBS STATISTICS ARE AVERAGED FROM 10/ 9/1993 TO 28/ 9/1993
MEAN STATISTICS FOR AREA 400 HEIGHT T+72
OPER NOBS= 453 450 457 453 452 454 430 347
TRIAL NOBS= 453 450 457 453 452 454 429 348



VER V. OBS STATISTICS ARE AVERAGED FROM 10/ 9/1993 TO 28/ 9/1993
RMS STATISTICS FOR AREA 400 HEIGHT T+72

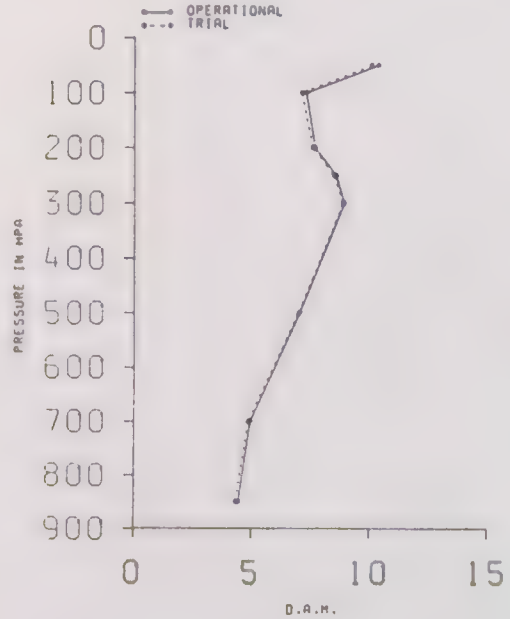
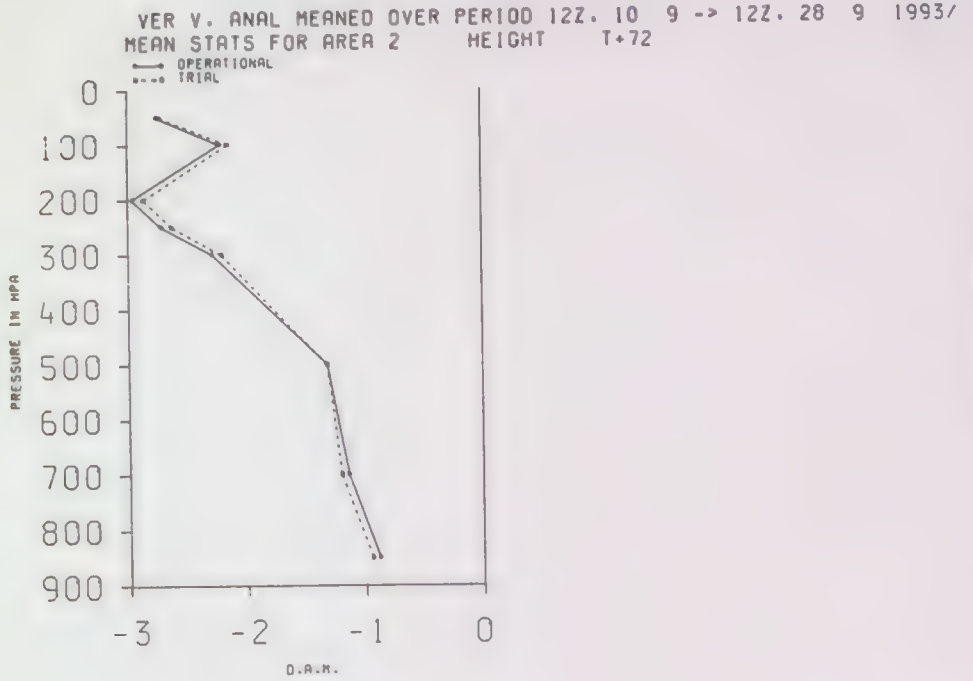
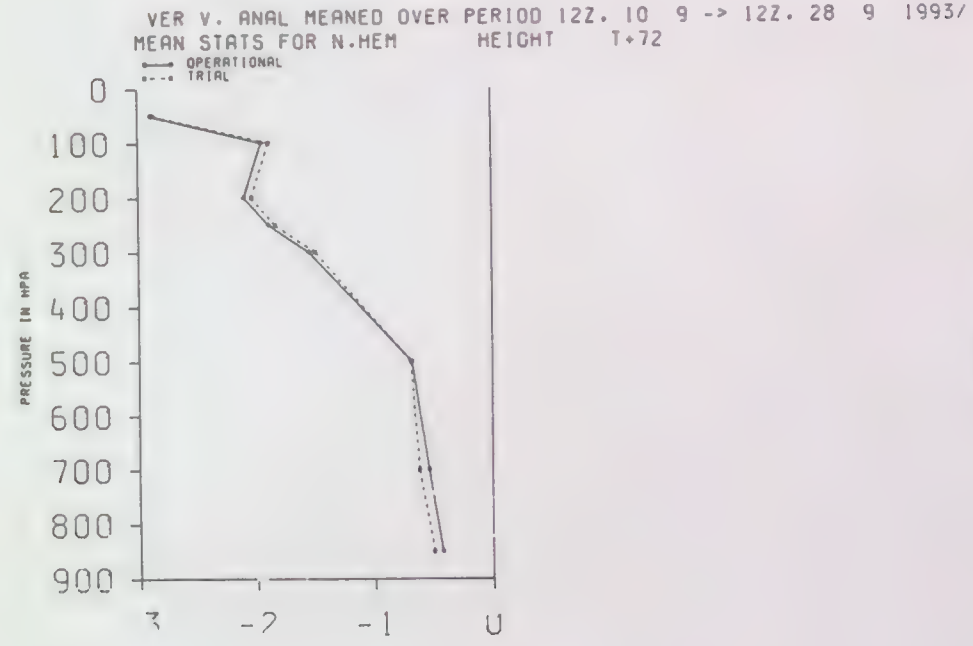


Fig 4.06


VER V. ANAL MEANED OVER PERIOD 12Z. 10 9 -> 12Z. 28 9 1993/
MEAN STATS FOR AREA 2 HEIGHT T+72
OPERATIONAL
TRIAL
PRESSURE IN HPA
0
100
200
300
400
500
600
700
800
900
-3
-2
-1
0
D.A.M.

VER V. ANAL MEANED OVER PERIOD 12Z. 10 9 -> 12Z. 28 9 1993/
RMS STATS FOR AREA 2 HEIGHT T+72
OPERATIONAL
TRIAL
PRESSURE IN HPA
0
100
200
300
400
500
600
700
800
900
2
4
6
8
D.A.M.


VER V. ANAL MEANED OVER PERIOD 12Z. 10 9 -> 12Z. 28 9 1993/
MEAN STATS FOR N.HEM HEIGHT T+72
OPERATIONAL
TRIAL
PRESSURE IN HPA
0
100
200
300
400
500
600
700
800
900
-2
-1
0

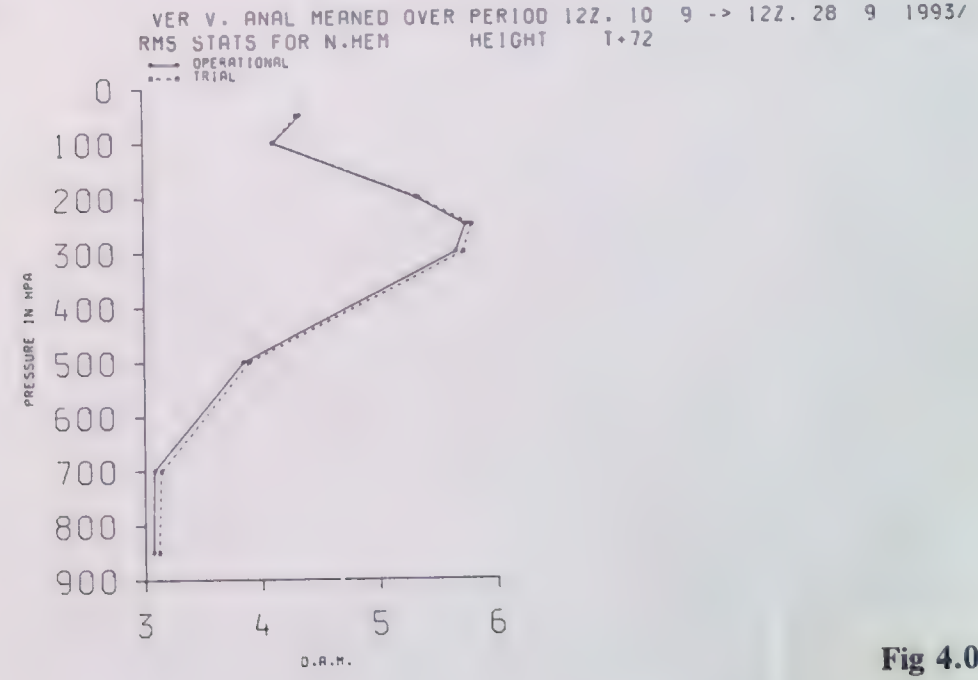
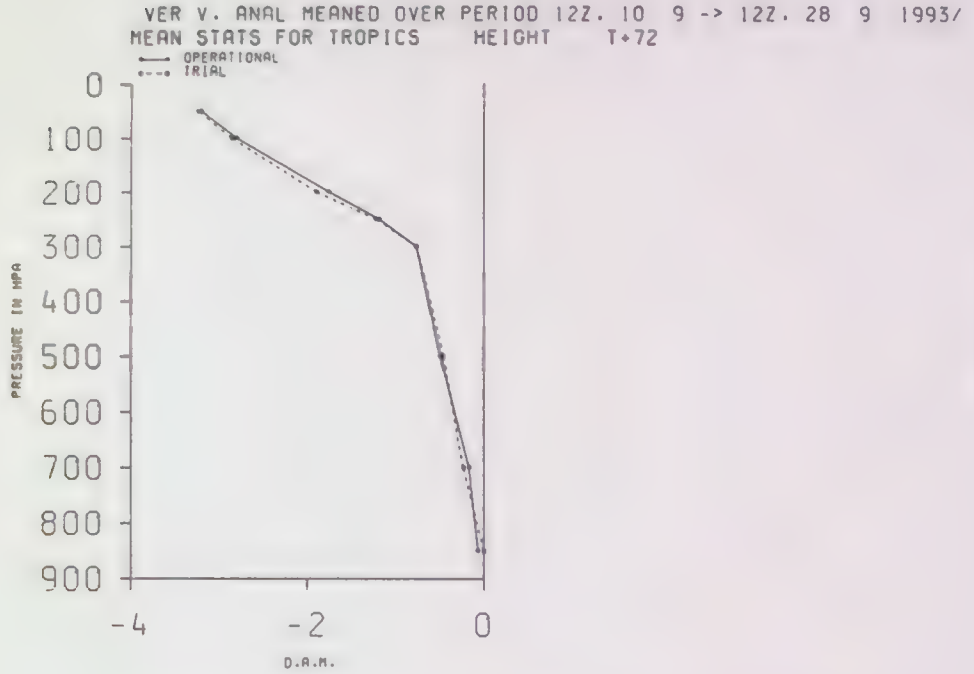
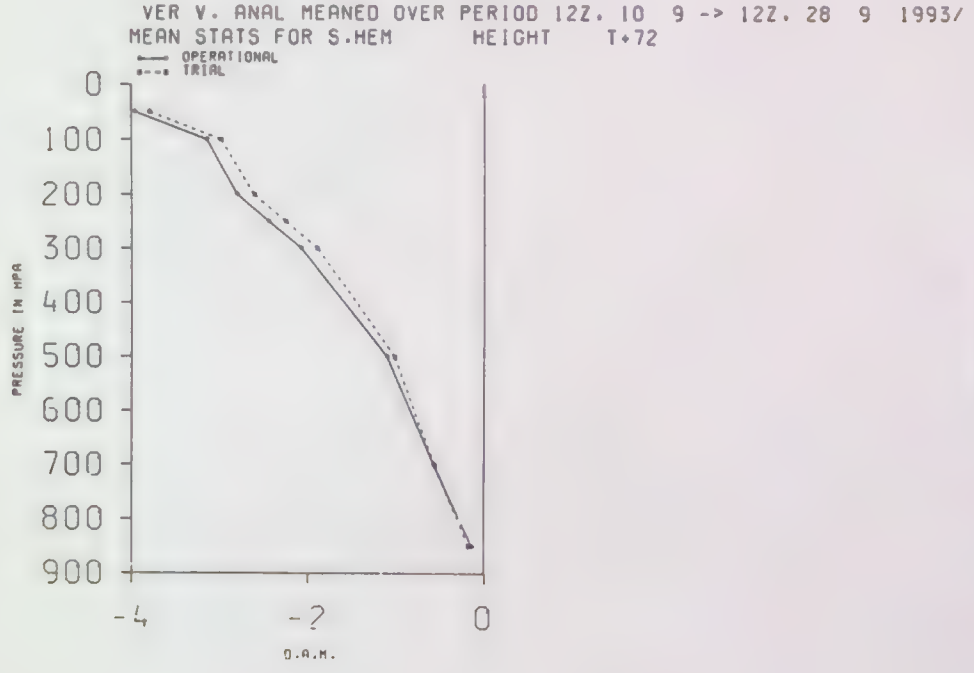

VER V. ANAL MEANED OVER PERIOD 12Z. 10 9 -> 12Z. 28 9 1993/
RMS STATS FOR N.HEM HEIGHT T+72
OPERATIONAL
TRIAL
PRESSURE IN HPA
0
100
200
300
400
500
600
700
800
900
3
4
5
6
D.A.M.

Fig 4.07


VER V. ANAL MEANED OVER PERIOD 12Z. 10 9 -> 12Z. 28 9 1993/
MEAN STATS FOR TROPICS HEIGHT T+72
OPERATIONAL
TRIAL
PRESSURE IN MPA
0
100
200
300
400
500
600
700
800
900
-4
-2
0
D.A.M.

VER V. ANAL MEANED OVER PERIOD 12Z. 10 9 -> 12Z. 28 9 1993/
RMS STATS FOR TROPICS HEIGHT T+72
OPERATIONAL
TRIAL
PRESSURE IN MPA
0
100
200
300
400
500
600
700
800
900
1
2
3
4
D.A.M.


VER V. ANAL MEANED OVER PERIOD 12Z. 10 9 -> 12Z. 28 9 1993/
MEAN STATS FOR S.HEM HEIGHT T+72
OPERATIONAL
TRIAL
PRESSURE IN MPA
0
100
200
300
400
500
600
700
800
900
-4
-2
0
D.A.M.

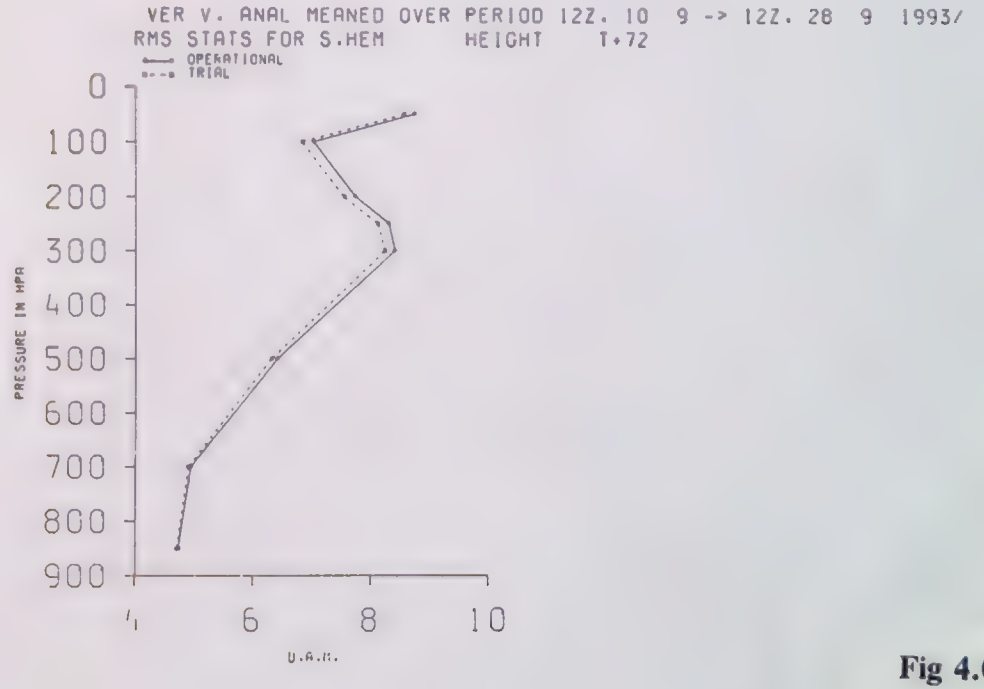
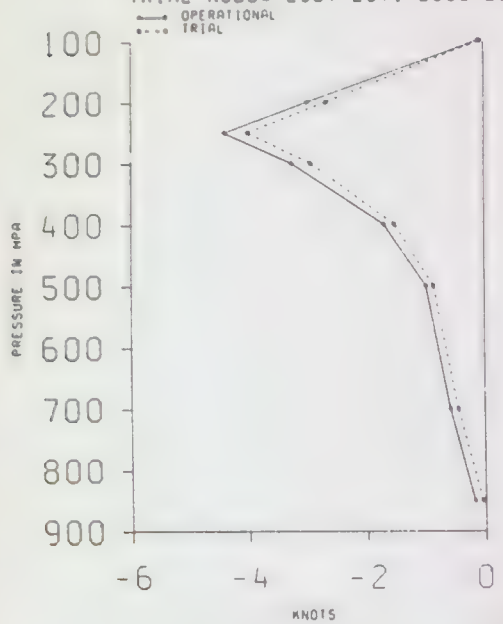
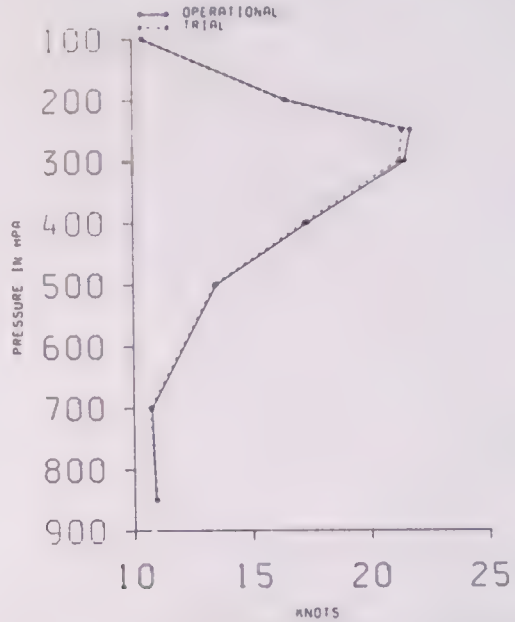

VER V. ANAL MEANED OVER PERIOD 12Z. 10 9 -> 12Z. 28 9 1993/
RMS STATS FOR S.HEM HEIGHT T+72
OPERATIONAL
TRIAL
PRESSURE IN MPA
0
100
200
300
400
500
600
700
800
900
4
6
8
10
D.A.M.

Fig 4.08

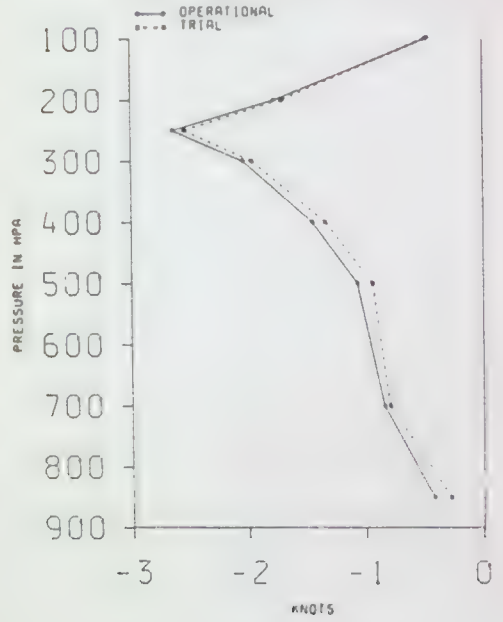
VER V. OBS STATISTICS ARE AVERAGED FROM 10/ 9/1993 TO 28/ 9/1993
MEAN STATISTICS FOR AREA 2 WIND T+48
OPER NOBS= 2367 2372 2358 2347 2306 2305 2268 2161
TRIAL NOBS= 2367 2371 2358 2347 2306 2304 2269 2161



VER V. OBS STATISTICS ARE AVERAGED FROM 10/ 9/1993 TO 28/ 9/1993
RMS STATISTICS FOR AREA 2 WIND T+48



VER V. OBS STATISTICS ARE AVERAGED FROM 10/ 9/1993 TO 28/ 9/1993
MEAN STATISTICS FOR AREA 200 WIND T+48
OPER NOBS= 5960 6198 6252 6218 6119 6062 5965 5562
TRIAL NOBS= 5960 6197 6253 6218 6118 6062 5966 5561



VER V. OBS STATISTICS ARE AVERAGED FROM 10/ 9/1993 TO 28/ 9/1993
RMS STATISTICS FOR AREA 200 WIND T+48

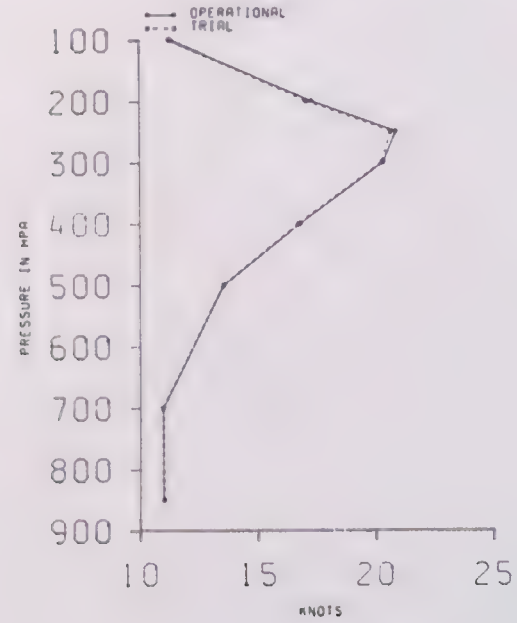
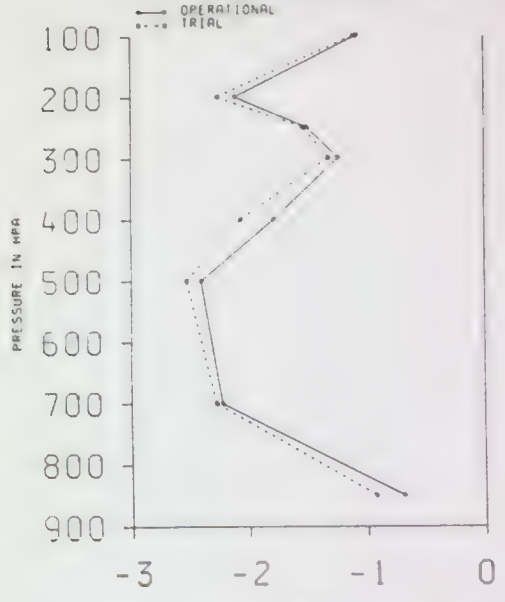
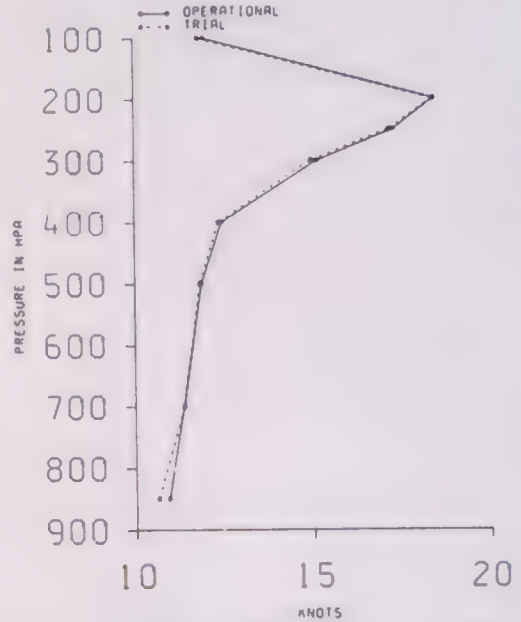


Fig 4.09

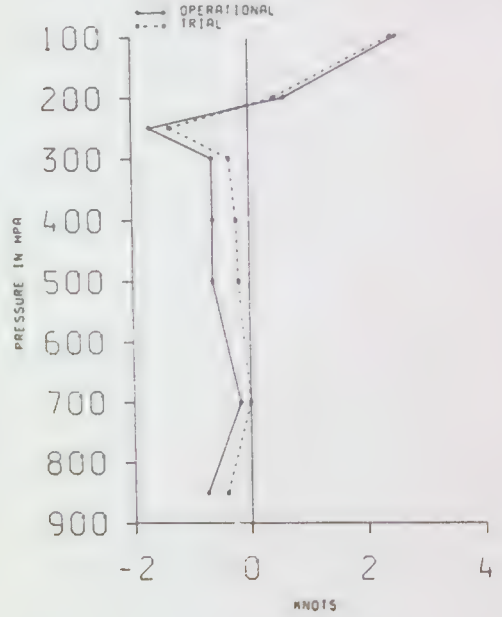
VER V. OBS STATISTICS ARE AVERAGED FROM 10/ 9/1993 TO 28/ 9/1993
MEAN STATISTICS FOR AREA 300 WIND T+48
OPER NOBS= 2296 2405 2361 2314 2284 2242 2202 2013
TRIAL NOBS= 2296 2405 2361 2313 2284 2242 2202 2013



VER V. OBS STATISTICS ARE AVERAGED FROM 10/ 9/1993 TO 28/ 9/1993
RMS STATISTICS FOR AREA 300 WIND T+48



VER V. OBS STATISTICS ARE AVERAGED FROM 10/ 9/1993 TO 28/ 9/1993
MEAN STATISTIC' FOR AREA 400 WIND T+48
OPER NOBS= 338 339 337 333 331 324 324 305
TRIAL NOBS= 337 338 337 331 331 325 324 305



VER V. OBS STATISTICS ARE AVERAGED FROM 10/ 9/1993 TO 28/ 9/1993
RMS STATISTICS FOR AREA 400 WIND T+48

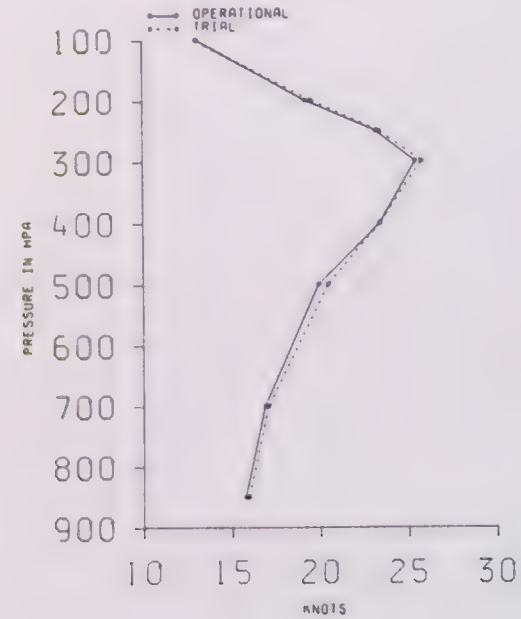
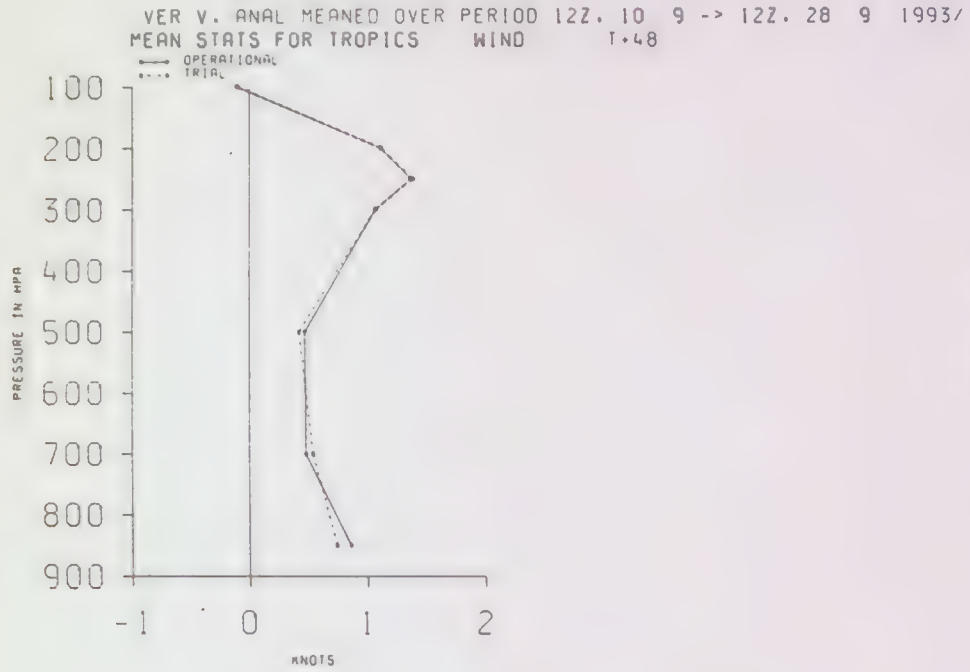
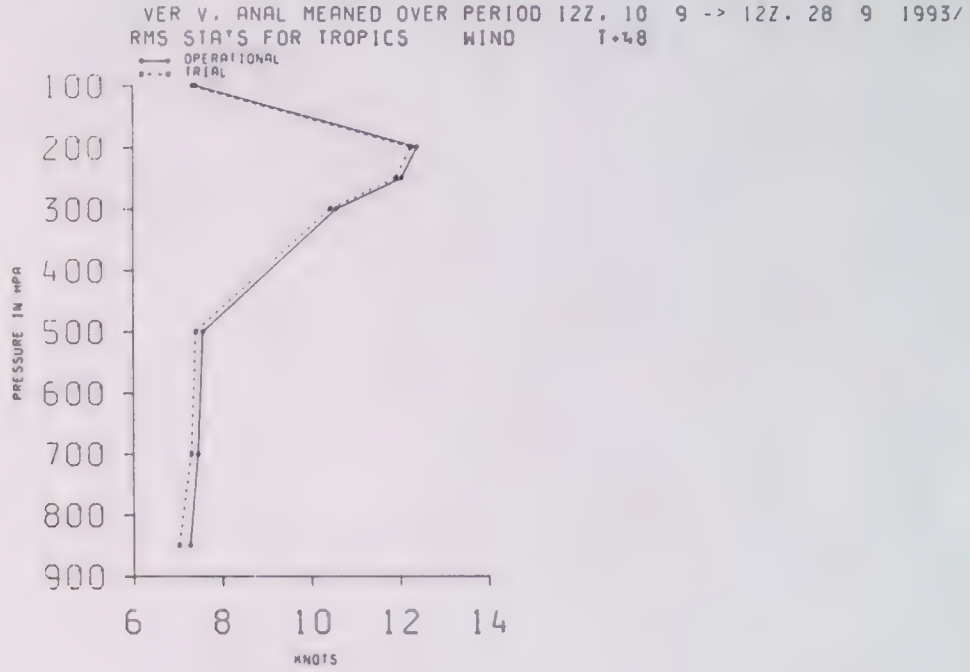
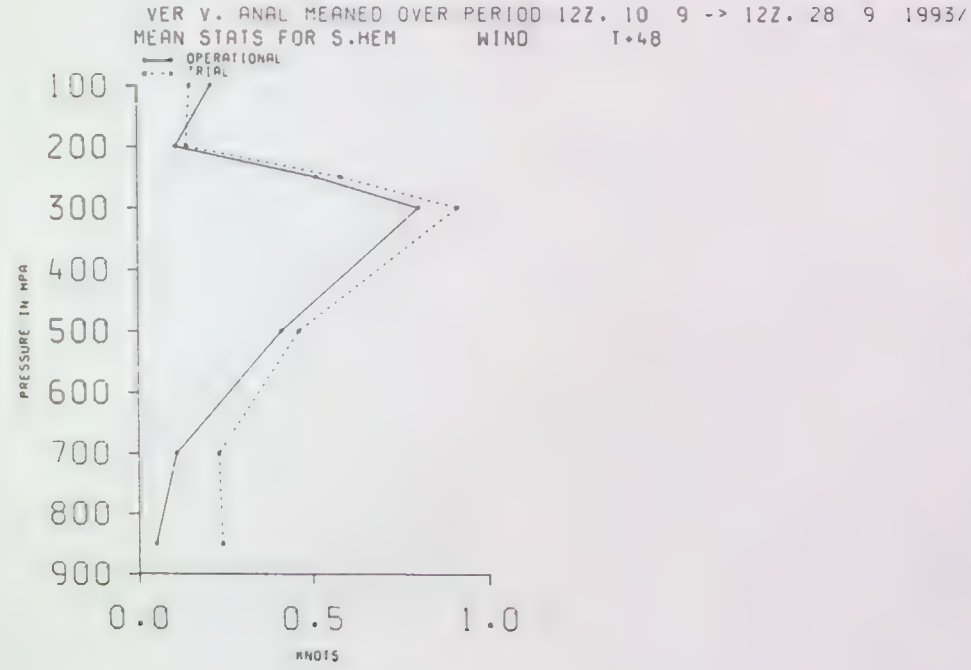


Fig 4.10


VER V. ANAL MEANED OVER PERIOD 12Z. 10 9 -> 12Z. 28 9 1993/
MEAN STATS FOR TROPICS WIND T+48
OPERATIONAL
TRIAL
PRESSURE IN MPA
100
200
300
400
500
600
700
800
900
-1
0
1
2
KNOTS


VER V. ANAL MEANED OVER PERIOD 12Z. 10 9 -> 12Z. 28 9 1993/
RMS STATS FOR TROPICS WIND T+48
OPERATIONAL
TRIAL
PRESSURE IN MPA
100
200
300
400
500
600
700
800
900
6
8
10
12
14
KNOTS

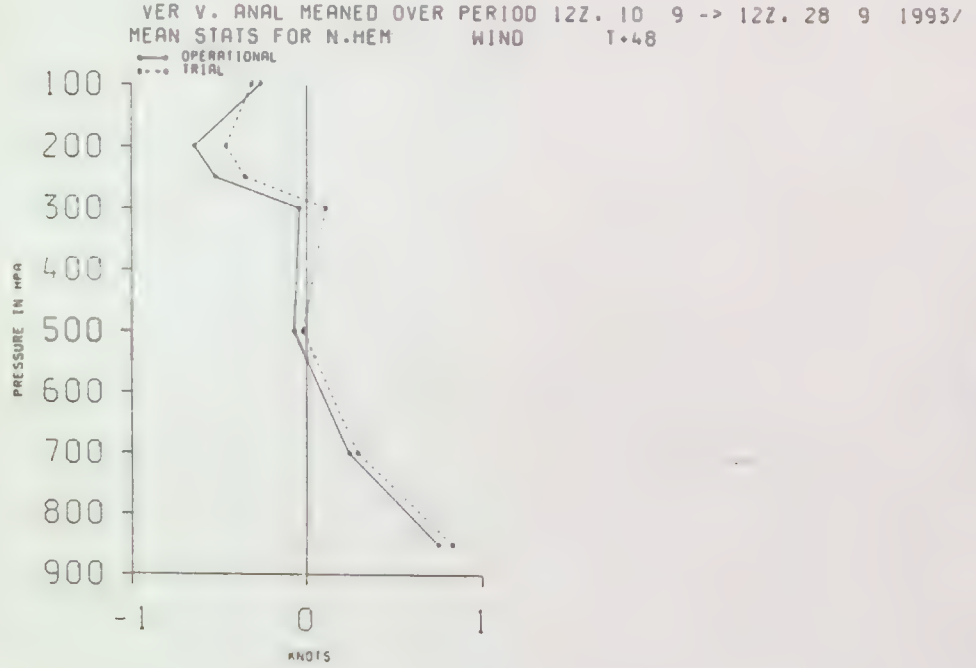

VER V. ANAL MEANED OVER PERIOD 12Z. 10 9 -> 12Z. 28 9 1993/
MEAN STATS FOR S.HEM WIND T+48
OPERATIONAL
TRIAL
PRESSURE IN MPA
100
200
300
400
500
600
700
800
900
0.0
0.5
1.0
KNOTS

VER V. ANAL MEANED OVER PERIOD 12Z. 10 9 -> 12Z. 28 9 1993/
RMS STATS FOR S.HEM WIND T+48
OPERATIONAL
TRIAL
PRESSURE IN MPA
100
200
300
400
500
600
700
800
900
5
10
15
20
25
KNOTS

Fig 4.11

VER V. ANAL MEANED OVER PERIOD 12Z. 10 9 -> 12Z. 28 9 1993/
MEAN STATS FOR AREA 2 WIND T+48
OPERATIONAL
TRIAL
PRESSURE IN HPA
100
200
300
400
500
600
700
800
900
-2
-1
0
1
KNOTS

VER V. ANAL MEANED OVER PERIOD 12Z. 10 9 -> 12Z. 28 9 1993/
RMS STATS FOR AREA 2 WIND T+48
OPERATIONAL
TRIAL
PRESSURE IN HPA
100
200
300
400
500
600
700
800
900
5
10
15
20
KNOTS


VER V. ANAL MEANED OVER PERIOD 12Z. 10 9 -> 12Z. 28 9 1993/
MEAN STATS FOR N.HEM WIND T+48
OPERATIONAL
TRIAL
PRESSURE IN HPA
100
200
300
400
500
600
700
800
900
-1
0
1
KNOTS

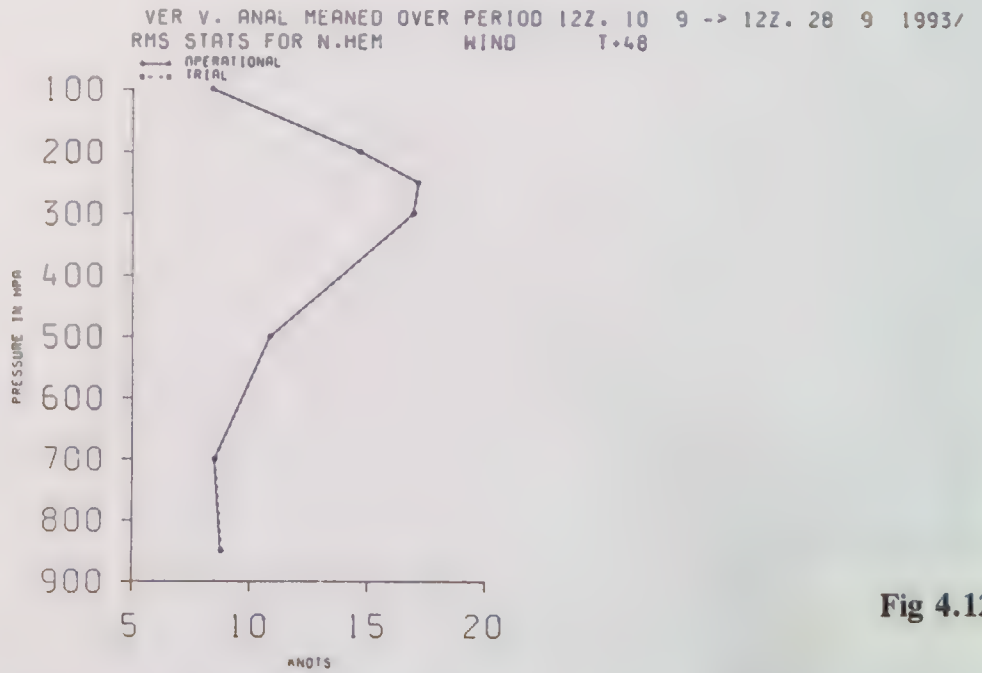

VER V. ANAL MEANED OVER PERIOD 12Z. 10 9 -> 12Z. 28 9 1993/
RMS STATS FOR N.HEM WIND T+48
OPERATIONAL
TRIAL
PRESSURE IN HPA
100
200
300
400
500
600
700
800
900
5
10
15
20
KNOTS

Fig 4.12

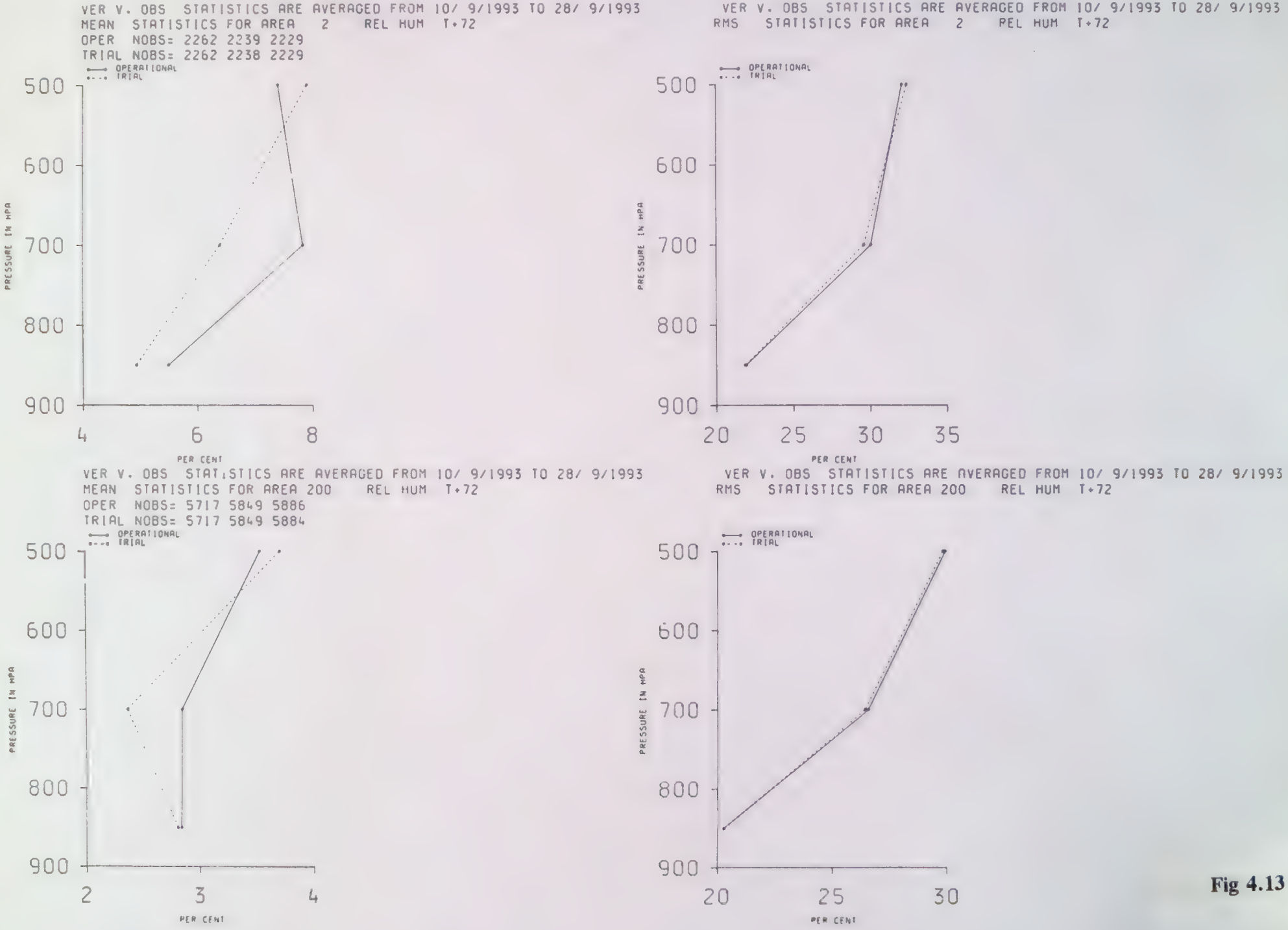
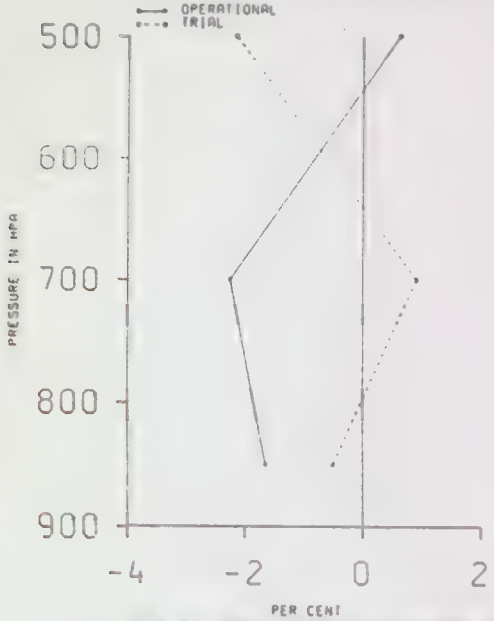
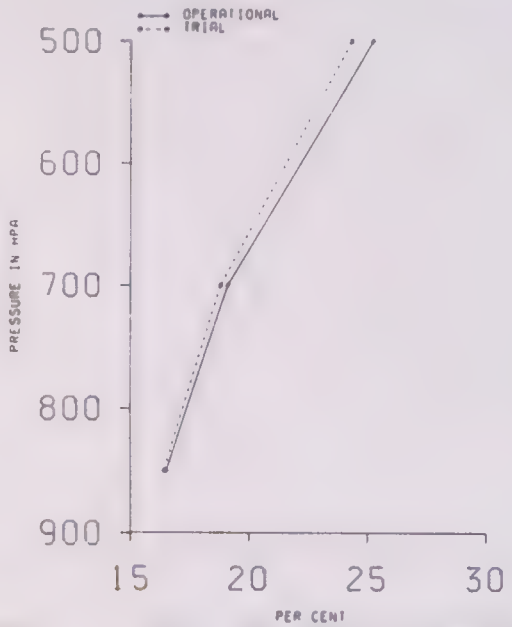

VER V. OBS STATISTICS ARE AVERAGED FROM 10/ 9/1993 TO 28/ 9/1993
MEAN STATISTICS FOR AREA 2 REL HUM T+72
OPER NOBS= 2262 2239 2229
TRIAL NOBS= 2262 2238 2229
OPERATIONAL
TRIAL
PRESSURE IN MPA
500
600
700
800
900
4
6
8
PER CENT
VER V. OBS STATISTICS ARE AVERAGED FROM 10/ 9/1993 TO 28/ 9/1993
RMS STATISTICS FOR AREA 2 REL HUM T+72
OPERATIONAL
TRIAL
PRESSURE IN MPA
500
600
700
800
900
20
25
30
35
PER CENT
VER V. OBS STATISTICS ARE AVERAGED FROM 10/ 9/1993 TO 28/ 9/1993
MEAN STATISTICS FOR AREA 200 REL HUM T+72
OPER NOBS= 5717 5849 5886
TRIAL NOBS= 5717 5849 5884
OPERATIONAL
TRIAL
PRESSURE IN MPA
500
600
700
800
900
2
3
4
PER CENT
VER V. OBS STATISTICS ARE AVERAGED FROM 10/ 9/1993 TO 28/ 9/1993
RMS STATISTICS FOR AREA 200 REL HUM T+72
OPERATIONAL
TRIAL
PRESSURE IN MPA
500
600
700
800
900
20
25
30
PER CENT

Fig 4.13

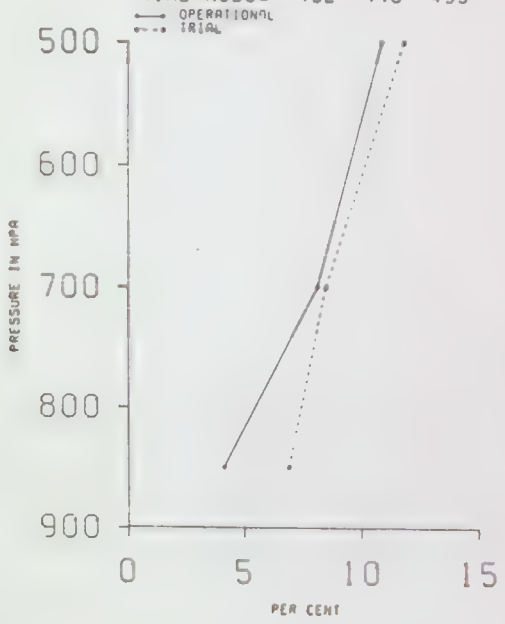
VER V. OBS STATISTICS ARE AVERAGED FROM 10/ 9/1993 TO 28/ 9/1993
MEAN STATISTICS FOR AREA 300 REL HUM T+72
OPER NOBS= 2232 2345 2314
TRIAL NOBS= 2232 2345 2314



VER V. OBS STATISTICS ARE AVERAGED FROM 10/ 9/1993 TO 28/ 9/1993
RMS STATISTICS FOR AREA 300 REL HUM T+72



VER V. OBS STATISTICS ARE AVERAGED FROM 10/ 9/1993 TO 28/ 9/1993
MEAN STATISTICS FOR AREA 400 REL HUM T+72
OPER NOBS= 454 445 436
TRIAL NOBS= 452 446 435



VER V. OBS STATISTICS ARE AVERAGED FROM 10/ 9/1993 TO 28/ 9/1993
RMS STATISTICS FOR AREA 400 REL HUM T+72

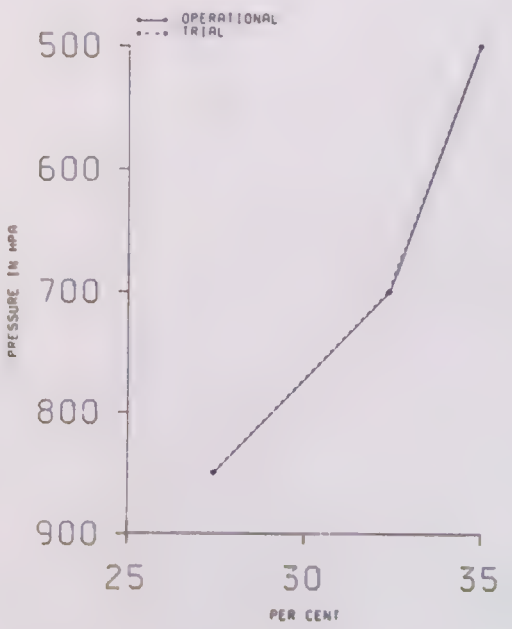
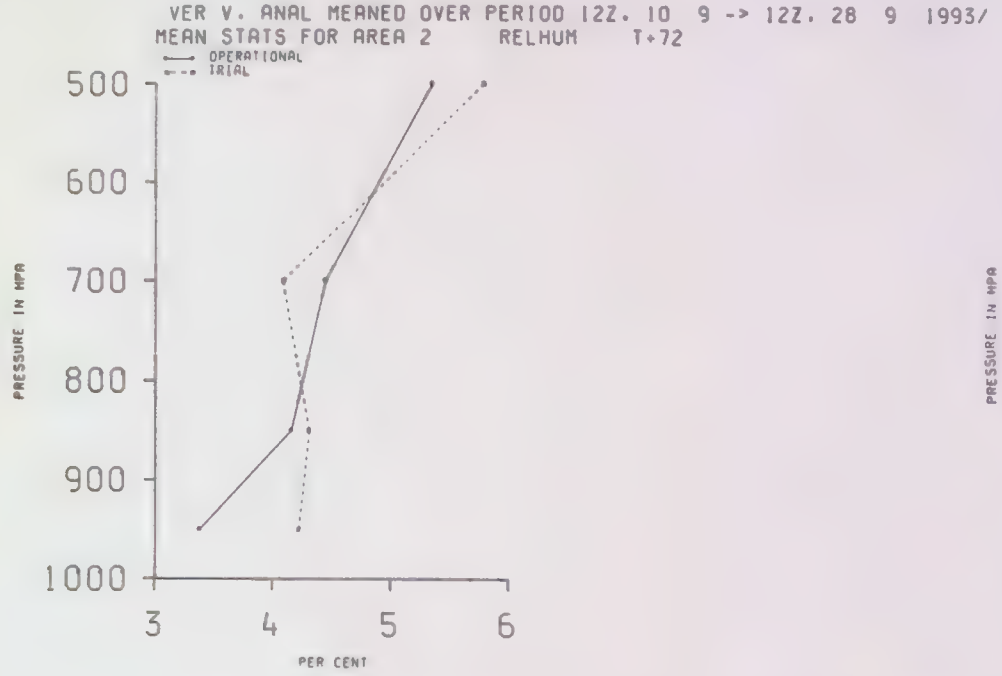
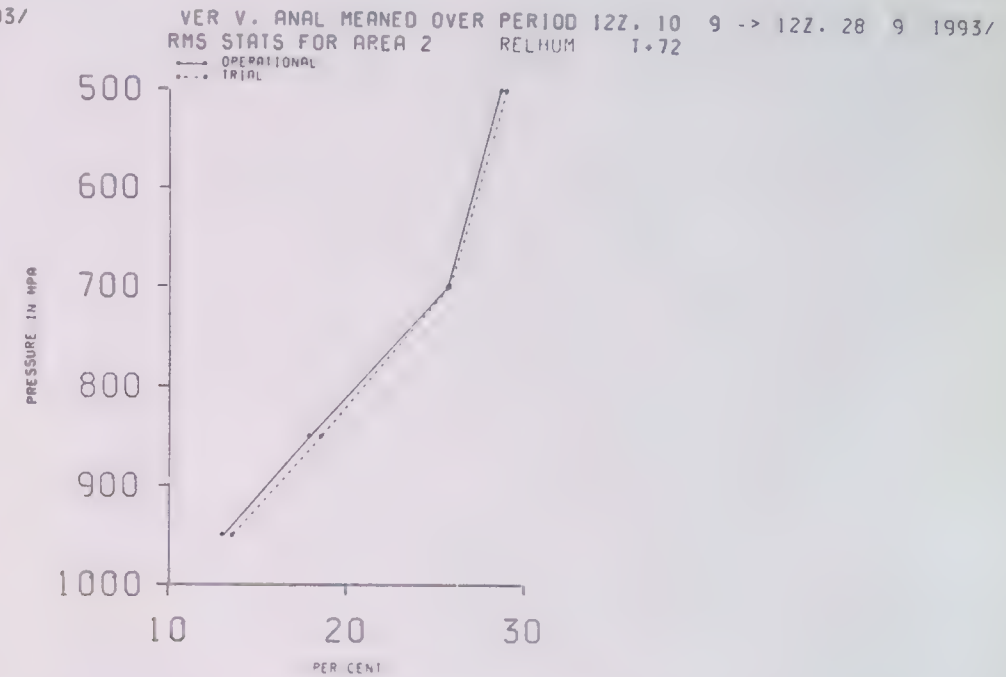
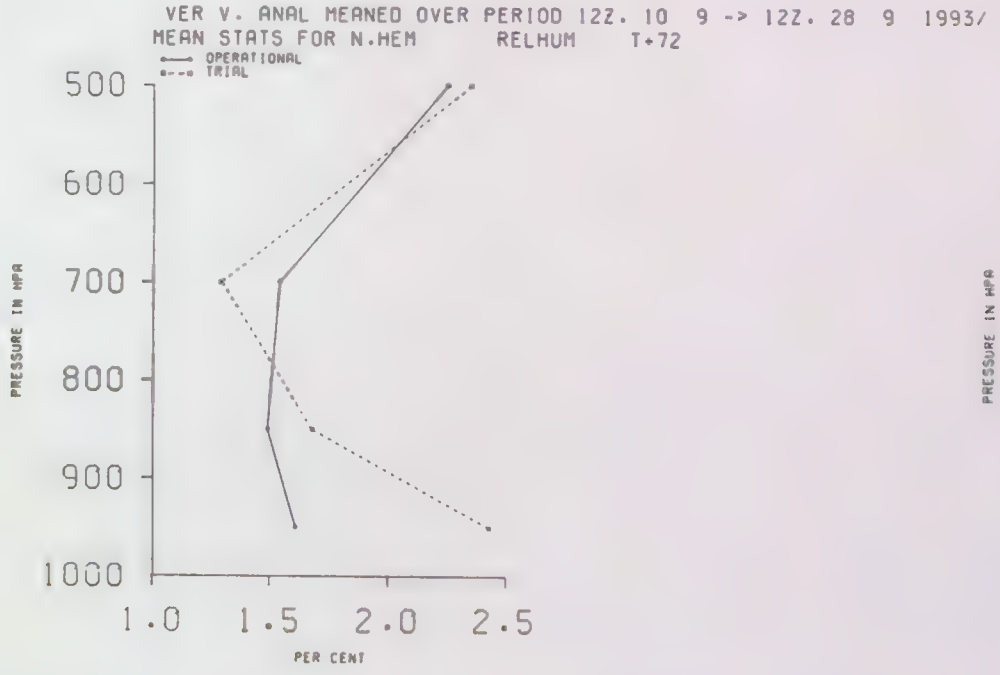


Fig 4.14


VER V. ANAL MEANED OVER PERIOD 12Z. 10 9 -> 12Z. 28 9 1993/
MEAN STATS FOR AREA 2 RELHUM T+72
OPERATIONAL
TRIAL
PRESSURE IN MPA
500
600
700
800
900
1000
3
4
5
6
PER CENT


VER V. ANAL MEANED OVER PERIOD 12Z. 10 9 -> 12Z. 28 9 1993/
RMS STATS FOR AREA 2 RELHUM T+72
OPERATIONAL
TRIAL
PRESSURE IN MPA
500
600
700
800
900
1000
10
20
30
PER CENT


VER V. ANAL MEANED OVER PERIOD 12Z. 10 9 -> 12Z. 28 9 1993/
MEAN STATS FOR N.HEM RELHUM T+72
OPERATIONAL
TRIAL
PRESSURE IN MPA
500
600
700
800
900
1000
1.0
1.5
2.0
2.5
PER CENT

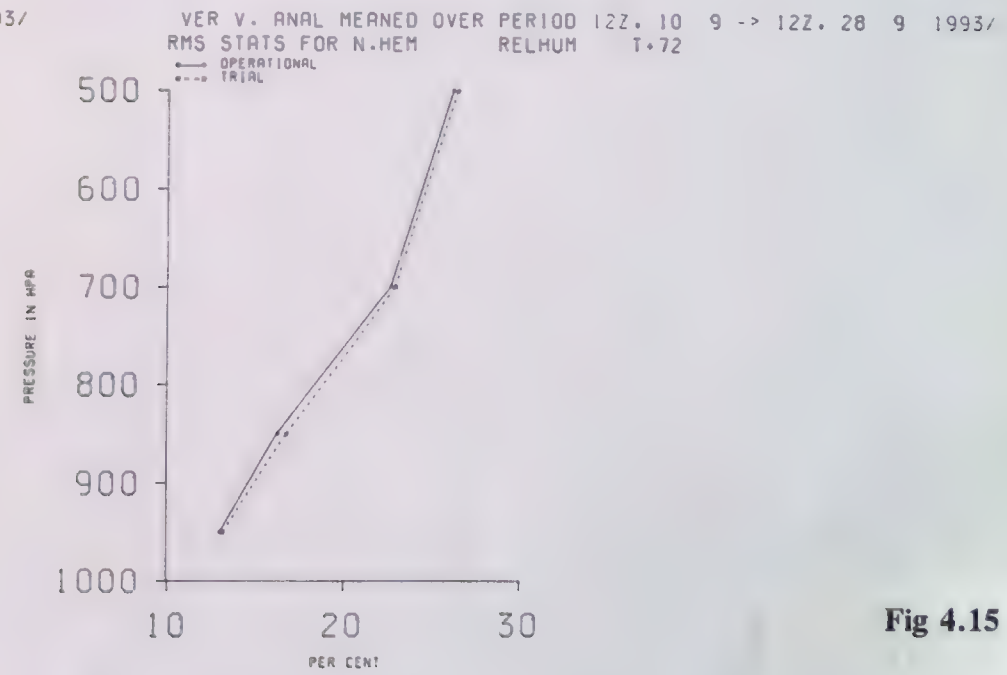
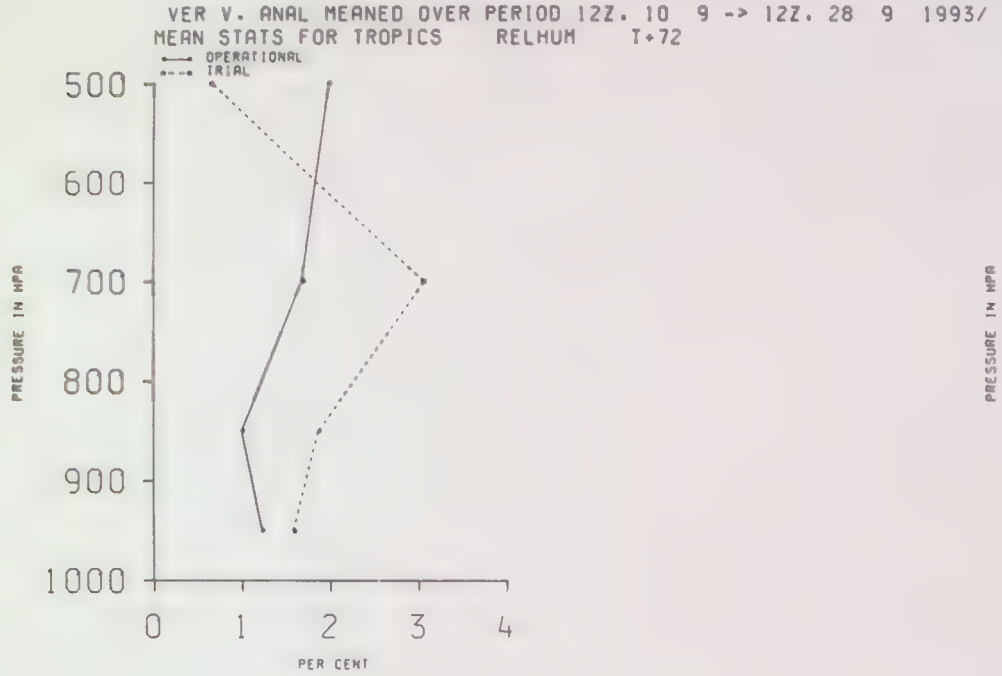
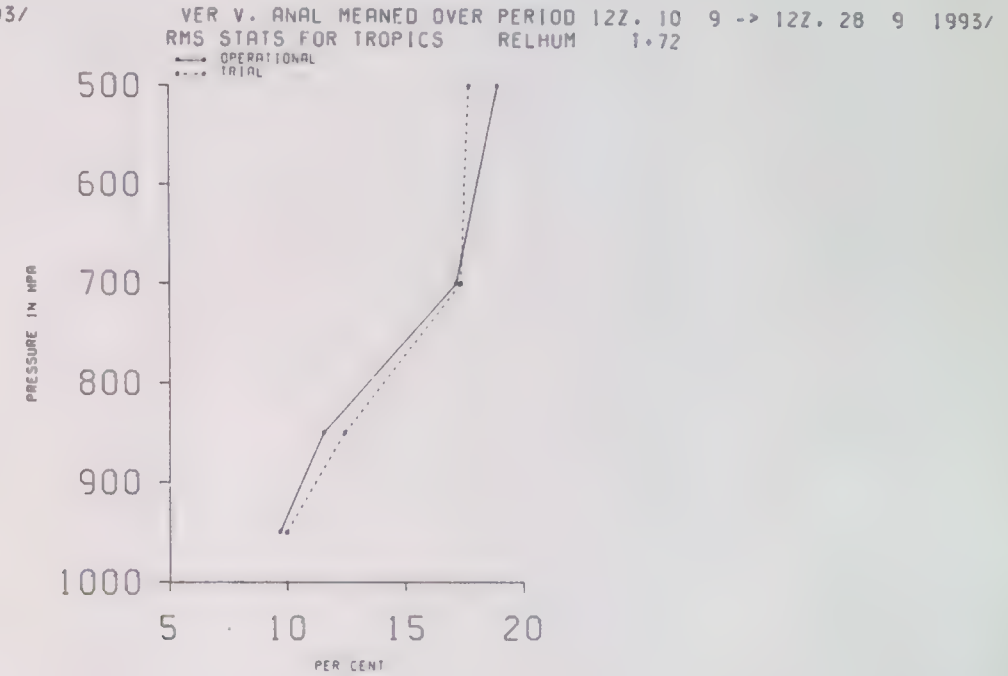
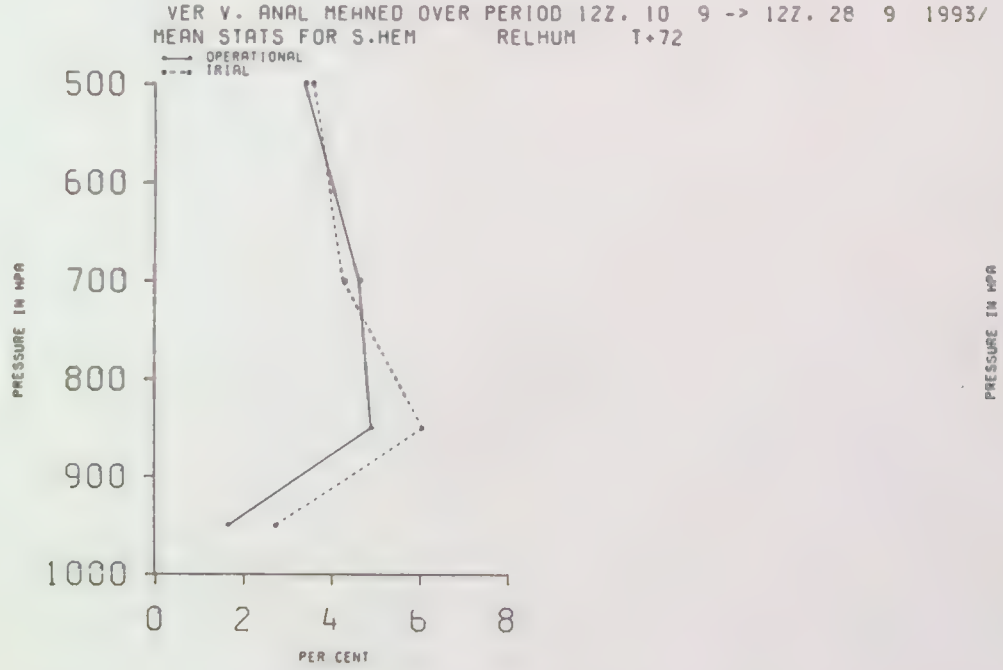

VER V. ANAL MEANED OVER PERIOD 12Z. 10 9 -> 12Z. 28 9 1993/
RMS STATS FOR N.HEM RELHUM T+72
OPERATIONAL
TRIAL
PRESSURE IN MPA
500
600
700
800
900
1000
10
20
30
PER CENT

Fig 4.15


VER V. ANAL MEANED OVER PERIOD 12Z. 10 9 -> 12Z. 28 9 1993/
MEAN STATS FOR TROPICS RELHUM T+72
OPERATIONAL
TRIAL
PRESSURE IN HPA
500
600
700
800
900
1000
0
1
2
3
4
PER CENT


VER V. ANAL MEANED OVER PERIOD 12Z. 10 9 -> 12Z. 28 9 1993/
RMS STATS FOR TROPICS RELHUM T+72
OPERATIONAL
TRIAL
PRESSURE IN HPA
500
600
700
800
900
1000
5
10
15
20
PER CENT


VER V. ANAL MEANED OVER PERIOD 12Z. 10 9 -> 12Z. 28 9 1993/
MEAN STATS FOR S.HEM RELHUM T+72
OPERATIONAL
TRIAL
PRESSURE IN HPA
500
600
700
800
900
1000
0
2
4
6
8
PER CENT

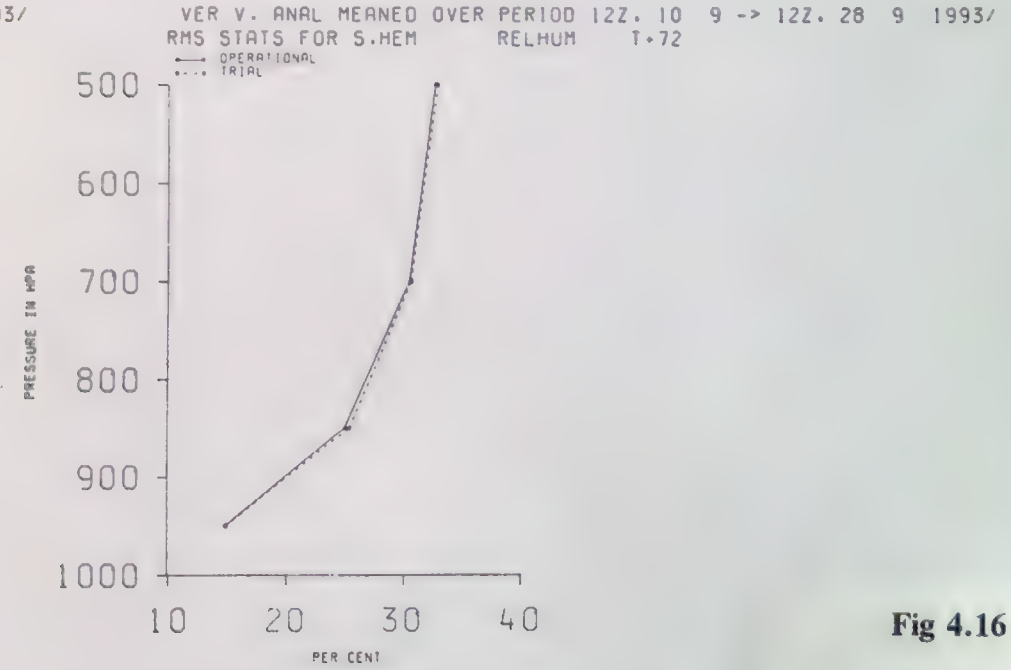

VER V. ANAL MEANED OVER PERIOD 12Z. 10 9 -> 12Z. 28 9 1993/
RMS STATS FOR S.HEM RELHUM T+72
OPERATIONAL
TRIAL
PRESSURE IN HPA
500
600
700
800
900
1000
10
20
30
40
PER CENT

Fig 4.16

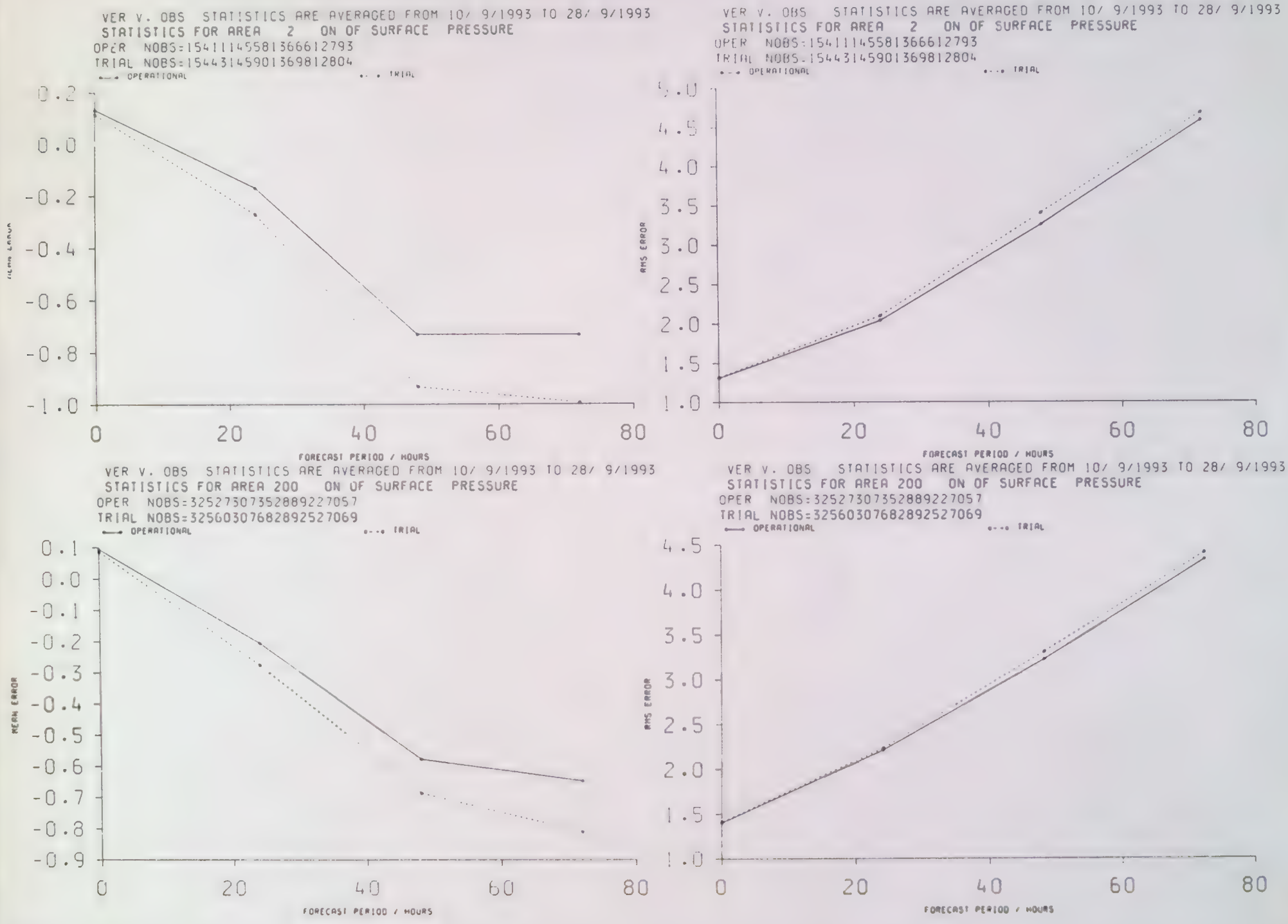

VER V. OBS STATISTICS ARE AVERAGED FROM 10/ 9/1993 TO 28/ 9/1993
STATISTICS FOR AREA 2 ON OF SURFACE PRESSURE
OPER NOBS=1541114558136661279 3
TRIAL NOBS=1544314590136981280 4
OPERATIONAL
TRIAL
MEAN ERROR
0.2
0.0
-0.2
-0.4
-0.6
-0.8
-1.0
0
20
40
60
80
FORECAST PERIOD / HOURS
VER V. OBS STATISTICS ARE AVERAGED FROM 10/ 9/1993 TO 28/ 9/1993
STATISTICS FOR AREA 2 ON OF SURFACE PRESSURE
OPER NOBS=1541114558136661279 3
TRIAL NOBS=1544314590136981280 4
OPERATIONAL
TRIAL
RMS ERROR
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0
20
40
60
80
FORECAST PERIOD / HOURS
VER V. OBS STATISTICS ARE AVERAGED FROM 10/ 9/1993 TO 28/ 9/1993
STATISTICS FOR AREA 200 ON OF SURFACE PRESSURE
OPER NOBS=3252730735288922705 7
TRIAL NOBS=3256030768289252706 9
OPERATIONAL
TRIAL
MEAN ERROR
0.1
0.0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
-0.7
-0.8
-0.9
0
20
40
60
80
FORECAST PERIOD / HOURS
VER V. OBS STATISTICS ARE AVERAGED FROM 10/ 9/1993 TO 28/ 9/1993
STATISTICS FOR AREA 200 ON OF SURFACE PRESSURE
OPER NOBS=3252730735288922705 7
TRIAL NOBS=3256030768289252706 9
OPERATIONAL
TRIAL
RMS ERROR
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0
20
40
60
80
FORECAST PERIOD / HOURS

Fig 4.17

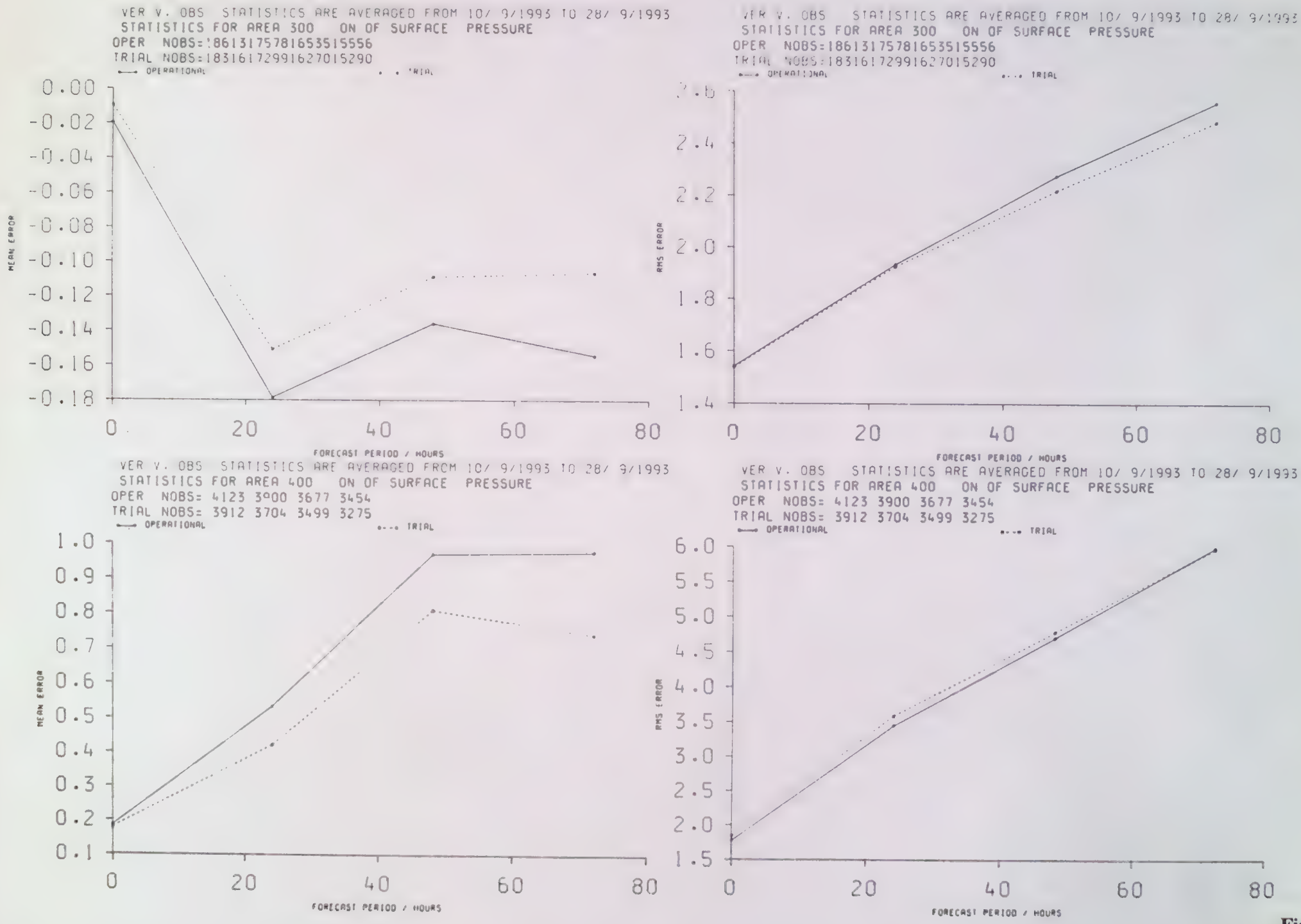
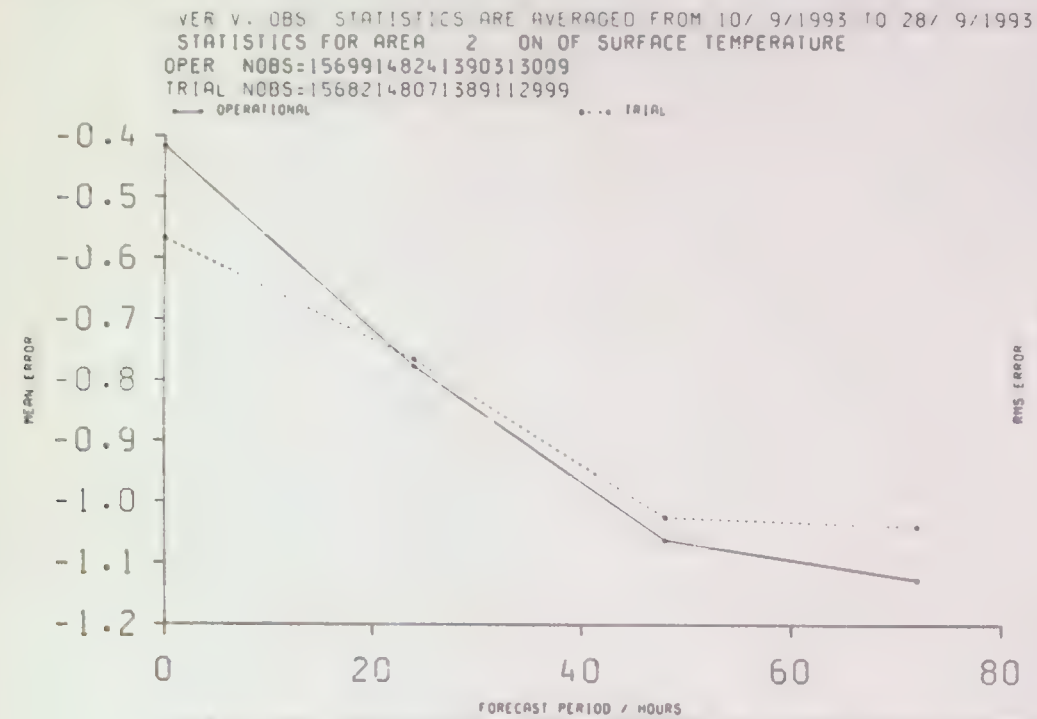
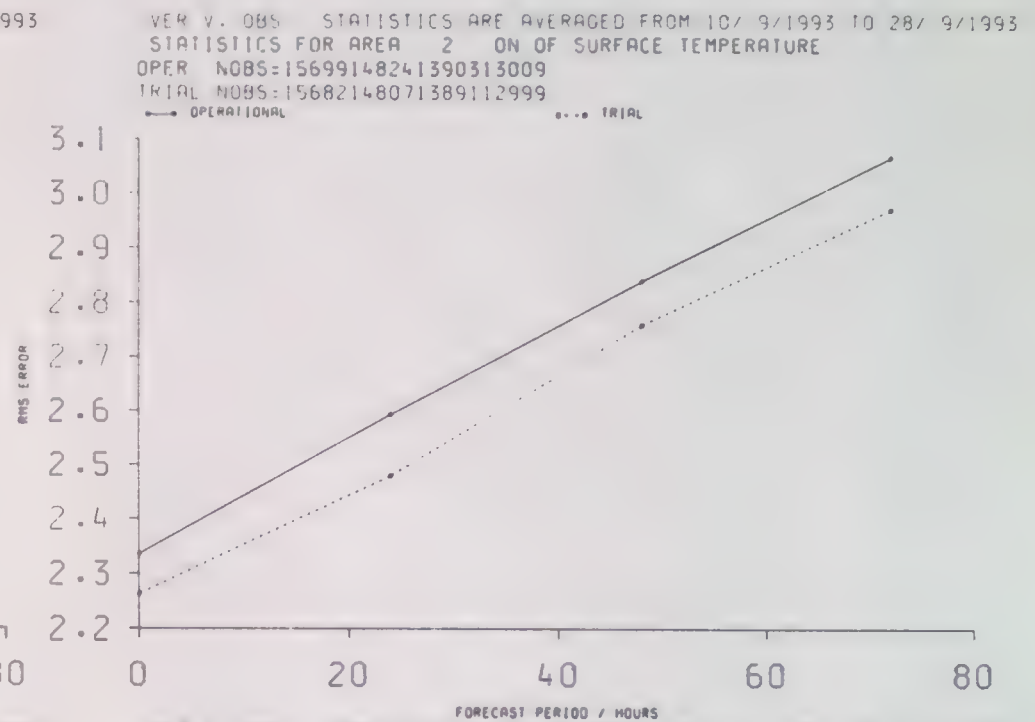
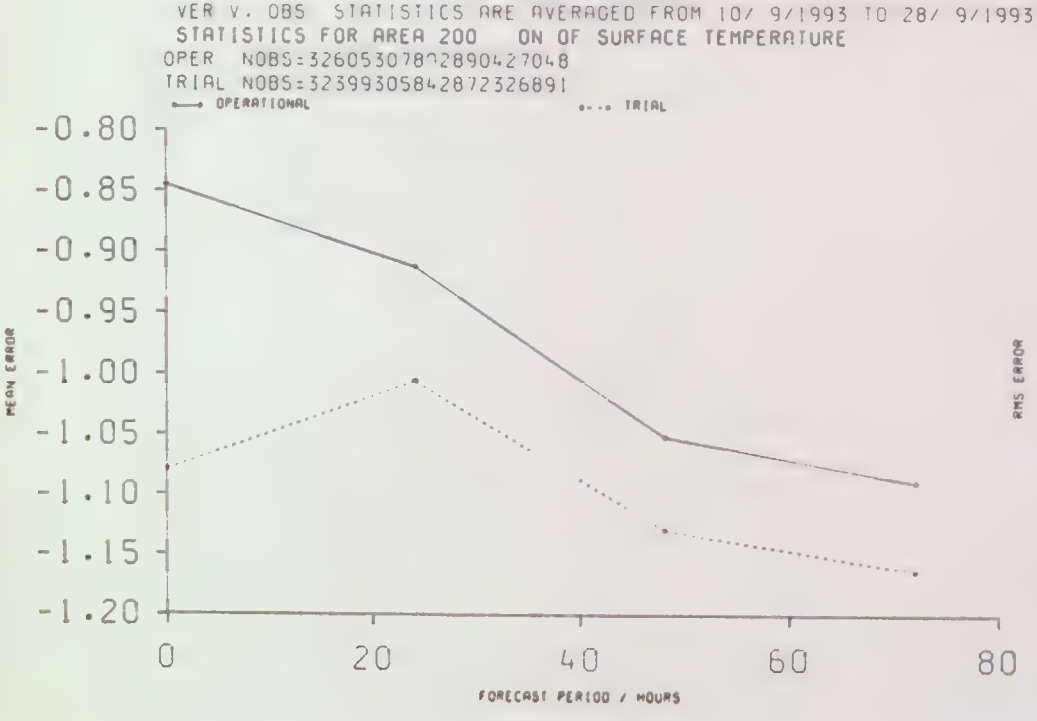

VER V. OBS STATISTICS ARE AVERAGED FROM 10/ 9/1993 TO 28/ 9/1993
STATISTICS FOR AREA 300 ON OF SURFACE PRESSURE
OPER NOBS=186131757816535155556
TRIAL NOBS=183161729916270152 90
OPERATIONAL
TRIAL
MEAN ERROR
0.00
-0.02
-0.04
-0.06
-0.08
-0.10
-0.12
-0.14
-0.16
-0.18
0
20
40
60
80
FORECAST PERIOD / HOURS
VER V. OBS STATISTICS ARE AVERAGED FROM 10/ 9/1993 TO 28/ 9/1993
STATISTICS FOR AREA 300 ON OF SURFACE PRESSURE
OPER NOBS=186131757816535155556
TRIAL NOBS=183161729916270152 90
OPERATIONAL
TRIAL
RMS ERROR
2.6
2.4
2.2
2.0
1.8
1.6
1.4
0
20
40
60
80
FORECAST PERIOD / HOURS
VER V. OBS STATISTICS ARE AVERAGED FROM 10/ 9/1993 TO 28/ 9/1993
STATISTICS FOR AREA 400 ON OF SURFACE PRESSURE
OPER NOBS= 4123 3900 3677 3454
TRIAL NOBS= 3912 3704 3499 3275
OPERATIONAL
TRIAL
MEAN ERROR
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
20
40
60
80
FORECAST PERIOD / HOURS
VER V. OBS STATISTICS ARE AVERAGED FROM 10/ 9/1993 TO 28/ 9/1993
STATISTICS FOR AREA 400 ON OF SURFACE PRESSURE
OPER NOBS= 4123 3900 3677 3454
TRIAL NOBS= 3912 3704 3499 3275
OPERATIONAL
TRIAL
RMS ERROR
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
0
20
40
60
80
FORECAST PERIOD / HOURS

Fig 4.18


VER V. OBS STATISTICS ARE AVERAGED FROM 10/ 9/1993 TO 28/ 9/1993
STATISTICS FOR AREA 2 ON OF SURFACE TEMPERATURE
OPER NOBS=1569914824139031300 9
TRIAL NOBS=1568214807138911299 9
OPERATIONAL
TRIAL
MEAN ERROR
-0.4
-0.5
-0.6
-0.7
-0.8
-0.9
-1.0
-1.1
-1.2
0
20
40
60
80
FORECAST PERIOD / HOURS


VER V. OBS STATISTICS ARE AVERAGED FROM 10/ 9/1993 TO 28/ 9/1993
STATISTICS FOR AREA 2 ON OF SURFACE TEMPERATURE
OPER NOBS=1569914824139031300 9
TRIAL NOBS=1568214807138911299 9
OPERATIONAL
TRIAL
RMS ERROR
3.1
3.0
2.9
2.8
2.7
2.6
2.5
2.4
2.3
2.2
0
20
40
60
80
FORECAST PERIOD / HOURS


VER V. OBS STATISTICS ARE AVERAGED FROM 10/ 9/1993 TO 28/ 9/1993
STATISTICS FOR AREA 200 ON OF SURFACE TEMPERATURE
OPER NOBS=3260530789289042 7048
TRIAL NOBS=3239930584287232 6891
OPERATIONAL
TRIAL
MEAN ERROR
-0.80
-0.85
-0.90
-0.95
-1.00
-1.05
-1.10
-1.15
-1.20
0
20
40
60
80
FORECAST PERIOD / HOURS

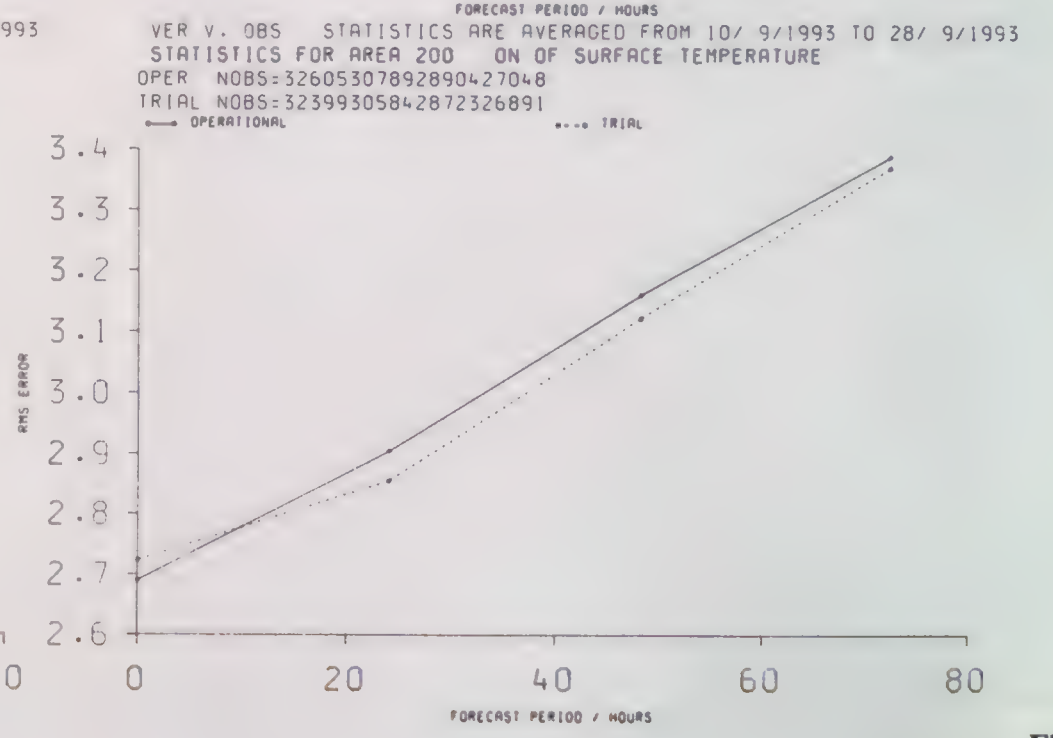

VER V. OBS STATISTICS ARE AVERAGED FROM 10/ 9/1993 TO 28/ 9/1993
STATISTICS FOR AREA 200 ON OF SURFACE TEMPERATURE
OPER NOBS=3260530789289042 7048
TRIAL NOBS=3239930584287232 6891
OPERATIONAL
TRIAL
RMS ERROR
3.4
3.3
3.2
3.1
3.0
2.9
2.8
2.7
2.6
0
20
40
60
80
FORECAST PERIOD / HOURS

Fig 4.19

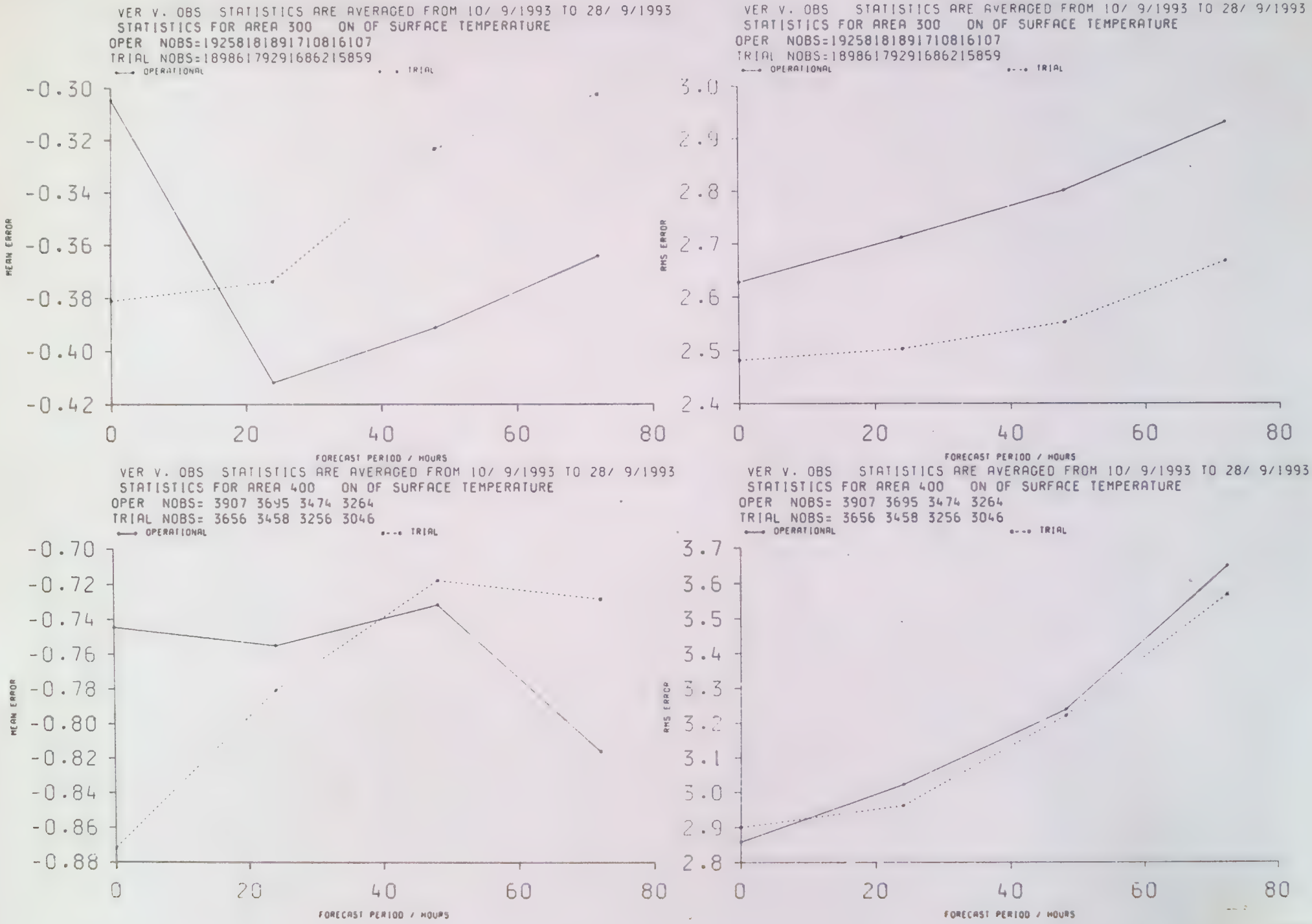

VER V. OBS STATISTICS ARE AVERAGED FROM 10/ 9/1993 TO 28/ 9/1993
STATISTICS FOR AREA 300 ON OF SURFACE TEMPERATURE
OPER NOBS=1925818189171081610 7
TRIAL NOBS=1898617929168621585 9
OPERATIONAL
TRIAL
MEAN ERROR
-0.30
-0.32
-0.34
-0.36
-0.38
-0.40
-0.42
0
20
40
60
80
FORECAST PERIOD / HOURS
VER V. OBS STATISTICS ARE AVERAGED FROM 10/ 9/1993 TO 28/ 9/1993
STATISTICS FOR AREA 300 ON OF SURFACE TEMPERATURE
OPER NOBS=1925818189171081610 7
TRIAL NOBS=1898617929168621585 9
OPERATIONAL
TRIAL
RMS ERROR
3.0
2.9
2.8
2.7
2.6
2.5
2.4
0
20
40
60
80
FORECAST PERIOD / HOURS
VER V. OBS STATISTICS ARE AVERAGED FROM 10/ 9/1993 TO 28/ 9/1993
STATISTICS FOR AREA 400 ON OF SURFACE TEMPERATURE
OPER NOBS= 3907 3695 3474 3264
TRIAL NOBS= 3656 3458 3256 3046
OPERATIONAL
TRIAL
MEAN ERROR
-0.70
-0.72
-0.74
-0.76
-0.78
-0.80
-0.82
-0.84
-0.86
-0.88
0
20
40
60
80
FORECAST PERIOD / HOURS
VER V. OBS STATISTICS ARE AVERAGED FROM 10/ 9/1993 TO 28/ 9/1993
STATISTICS FOR AREA 400 ON OF SURFACE TEMPERATURE
OPER NOBS= 3907 3695 3474 3264
TRIAL NOBS= 3656 3458 3256 3046
OPERATIONAL
TRIAL
RMS ERROR
3.7
3.6
3.5
3.4
3.3
3.2
3.1
3.0
2.9
2.8
0
20
40
60
80
FORECAST PERIOD / HOURS

Fig 4.20

TEMPERATURE %RMS CHANGE (TRIAL-OPERATIONAL)
STATISTICS FOR AREA 2
VERIFICATION AGAINST OBSERVATIONS

	T+0	T+24	T+48	T+72
850	(0.4)	0.8	0.3	(1.7)
700	(0.6)	(2.3)	(1.0)	(1.6)
500	(0.6)	0.2	(0.2)	1.0
300	0.1	(2.0)	(2.3)	(1.0)
250	0.0	0.9	0.9	(0.9)
200	0.0	(0.4)	0.4	(0.6)
100	0.0	0.8	0.5	(0.9)
50	0.0	0.8	0.6	1.4

TEMPERATURE %RMS CHANGE (TRIAL-OPERATIONAL)
STATISTICS FOR AREA 200
VERIFICATION AGAINST OBSERVATIONS

	T+0	T+24	T+48	T+72
850	0.9	1.6	1.4	0.6
700	0.5	0.1	0.8	0.6
500	0.5	0.3	(0.4)	0.6
300	0.0	0.2	(0.9)	(0.5)
250	0.2	1.3	0.8	(0.2)
200	0.0	0.1	0.7	0.6
100	(0.1)	0.2	(0.1)	(0.3)
50	0.0	0.0	(0.1)	0.6

TEMPERATURE %RMS CHANGE (TRIAL-OPERATIONAL)
STATISTICS FOR AREA 300
VERIFICATION AGAINST OBSERVATIONS

	T+0	T+24	T+48	T+72
850	(1.2)	(1.5)	(0.6)	(1.2)
700	1.9	3.4	1.7	0.6
500	(1.2)	(1.5)	(2.2)	(2.5)
300	(1.0)	(0.3)	(0.2)	1.6
250	0.2	1.9	2.0	0.9
200	2.0	4.2	6.5	5.7
100	0.1	(0.1)	(0.8)	(1.6)
50	0.4	1.0	1.7	1.6

TEMPERATURE %RMS CHANGE (TRIAL-OPERATIONAL)
STATISTICS FOR AREA 400
VERIFICATION AGAINST OBSERVATIONS

	T+0	T+24	T+48	T+72
850	(0.3)	0.2	(0.9)	(2.4)
700	0.2	0.7	(0.1)	(2.0)
500	0.5	(0.7)	0.6	(0.2)
300	0.1	0.6	0.8	(1.1)
250	(0.2)	(0.2)	(0.7)	(2.3)
200	(0.1)	(0.6)	(0.8)	(1.3)
100	(1.7)	(0.6)	0.2	(1.2)
50	0.5	0.9	1.1	0.6

Table 4.1 Percentage change in rms for temperature from verification against observations from trial 3. Reductions in brackets.

TEMP RMSE % CHANGE (TRIAL-OPERATIONAL)
AREA 1
VERIFICATION AGAINST ANALYSES

	T+24	T+48	T+72
850	1.9	1.2	0.0
700	(1.0)	(0.6)	0.0
500	(1.0)	0.6	0.9
300	(0.7)	(1.5)	(1.2)
250	0.7	(0.5)	(0.7)
200	0.7	0.0	0.4
100	0.0	0.9	0.0
50	1.5	0.0	1.6

TEMP RMSE % CHANGE (TRIAL-OPERATIONAL)
N.HEM
VERIFICATION AGAINST ANALYSES

	T+24	T+48	T+72
850	1.8	1.2	0.9
700	0.0	0.7	0.5
500	0.0	0.7	1.0
300	0.0	0.6	0.5
250	2.3	1.0	0.0
200	0.8	0.0	0.4
100	0.0	0.0	1.3
50	0.0	0.0	0.0

TEMP RMSE % CHANGE (TRIAL-OPERATIONAL)
TROPICS
VERIFICATION AGAINST ANALYSES

	T+24	T+48	T+72
850	(1.4)	2.9	3.1
700	(4.3)	(2.7)	(4.7)
500	(6.6)	(5.5)	(5.2)
300	0.0	(1.0)	(1.6)
250	3.8	4.3	2.8
200	8.5	9.3	9.8
100	(1.5)	(1.1)	(1.0)
50	(1.5)	(1.1)	0.0

TEMP RMSE % CHANGE (TRIAL-OPERATIONAL)
S.HEM
VERIFICATION AGAINST ANALYSES

	T+24	T+48	T+72
850	0.0	0.7	(0.6)
700	0.6	(0.8)	(2.1)
500	(0.7)	(1.8)	(2.1)
300	(0.8)	(1.1)	(0.4)
250	0.0	(0.9)	(1.5)
200	0.0	(1.8)	(2.1)
100	(1.1)	(1.3)	(1.0)
50	0.0	0.6	0.0

Table 4.2 Percentage change in rms for temperature from verification against analyses from trial 3. Reductions in brackets.

HEIGHT %RMS CHANGE (TRIAL-OPERATIONAL)
STATISTICS FOR AREA 2
VERIFICATION AGAINST OBSERVATIONS

	T+0	T+24	T+48	T+72
850	0.8	(0.4)	1.2	1.7
700	0.5	1.3	0.6	(0.2)
500	1.2	1.0	0.0	(1.0)
300	(0.4)	(0.7)	(1.6)	(1.7)
250	0.0	(0.6)	(1.7)	(2.0)
200	0.5	(0.1)	(1.8)	(2.8)
100	0.0	0.5	(0.7)	(2.1)
50	0.3	0.9	1.4	0.2

HEIGHT %RMS CHANGE (TRIAL-OPERATIONAL)
STATISTICS FOR AREA 200
VERIFICATION AGAINST OBSERVATIONS

	T+0	T+24	T+48	T+72
850	0.4	0.4	0.2	1.3
700	0.4	0.9	0.7	1.0
500	0.2	0.6	(0.2)	0.1
300	(0.4)	(0.1)	(1.0)	0.3
250	0.2	0.6	(1.1)	(0.3)
200	(0.1)	1.4	(0.8)	(0.7)
100	(0.1)	1.2	0.1	(0.5)
50	0.2	0.9	0.2	(0.4)

Table 4.3 Percentage change in rms for height from verification against observations from trial 3. Reductions in brackets.

HEIGHT %RMS CHANGE (TRIAL-OPERATIONAL)
STATISTICS FOR AREA 300
VERIFICATION AGAINST OBSERVATIONS

	T+0	T+24	T+48	T+72
850	(1.2)	(1.6)	(1.4)	(2.9)
700	(1.3)	0.7	1.1	0.4
500	(0.4)	(0.4)	(0.6)	(0.3)
300	(0.3)	(0.1)	(0.2)	(0.8)
250	0.4	0.4	(0.4)	(1.0)
200	0.1	1.3	0.9	0.3
100	0.1	0.6	0.5	0.1
50	0.1	1.0	1.0	1.3

HEIGHT %RMS CHANGE (TRIAL-OPERATIONAL)
STATISTICS FOR AREA 400
VERIFICATION AGAINST OBSERVATIONS

	T+0	T+24	T+48	T+72
850	2.8	0.6	0.6	(2.8)
700	0.4	0.7	0.2	(1.9)
500	1.8	1.5	0.8	(0.7)
300	0.8	1.5	1.1	(0.8)
250	0.7	0.9	0.4	(1.3)
200	0.9	1.0	0.0	(1.4)
100	(2.3)	0.3	(2.3)	(2.7)
50	2.4	1.0	(1.5)	(2.7)

HEIGHT RMSE % CHANGE (TRIAL-OPERATIONAL)
AREA
VERIFICATION AGAINST ANALYSES

	T+24	T+48	T+72
850	0.7	1.3	1.7
700	2.2	1.6	1.7
500	0.6	0.7	0.9
300	(0.4)	(0.2)	0.0
250	(0.4)	(0.9)	(0.4)
200	(0.4)	(1.1)	(0.8)
100	0.6	(1.3)	(0.5)
50	1.6	0.0	(0.5)

HEIGHT RMSE % CHANGE (TRIAL-OPERATIONAL)
N.HEM
VERIFICATION AGAINST ANALYSES

	T+24	T+48	T+72
850	0.7	0.4	1.6
700	1.6	1.4	1.9
500	0.7	0.8	1.3
300	0.0	0.3	1.1
250	0.9	0.0	0.9
200	0.9	(0.3)	0.4
100	1.6	0.0	0.0
50	1.4	(0.3)	(0.7)

HEIGHT RMSE % CHANGE (TRIAL-OPERATIONAL)
TROPICS
VERIFICATION AGAINST ANALYSES

	T+24	T+48	T+72
850	1.2	(2.8)	(1.6)
700	5.2	0.0	0.8
500	2.6	(1.9)	(0.8)
300	(1.0)	(2.0)	(0.5)
250	0.0	(1.1)	(0.4)
200	1.5	1.4	1.5
100	1.9	1.2	0.9
50	2.0	1.0	1.1

HEIGHT RMSE % CHANGE (TRIAL-OPERATIONAL)
S.HEM
VERIFICATION AGAINST ANALYSES

	T+24	T+48	T+72
850	0.9	0.0	(0.6)
700	0.9	(0.3)	(1.0)
500	0.4	(0.9)	(1.6)
300	(0.3)	(1.7)	(2.0)
250	(0.3)	(2.0)	(2.3)
200	(0.6)	(2.2)	(2.5)
100	(0.4)	(1.8)	(2.7)
50	(0.3)	(1.2)	(1.9)

Table 4.4 Percentage change in rms for height from verification against analyses from trial 3. Reductions in brackets.

WIND %RMS CHANGE (TRIAL-OPERATIONAL)
STATISTICS FOR AREA 2
VERIFICATION AGAINST OBSERVATIONS

	T+0	T+24	T+48	T+72
850	0.2	0.5	0.5	(0.3)
700	(0.6)	(0.6)	(0.8)	(0.4)
500	(0.2)	0.2	(0.6)	0.4
400	0.0	0.1	(0.8)	0.9
300	0.0	(0.3)	(1.1)	0.6
250	(0.3)	(0.8)	(1.6)	0.1
200	0.1	0.0	(0.3)	(0.8)
100	0.3	(0.4)	0.4	1.2

WIND %RMS CHANGE (TRIAL-OPERATIONAL)
STATISTICS FOR AREA 200
VERIFICATION AGAINST OBSERVATIONS

	T+0	T+24	T+48	T+72
850	0.0	(0.1)	0.3	0.4
700	(0.2)	(0.4)	(0.3)	(0.3)
500	0.1	0.4	(0.1)	0.2
400	0.1	0.1	(0.5)	0.6
300	0.0	0.2	(0.3)	0.6
250	0.0	0.1	(1.0)	(0.1)
200	0.0	0.2	(1.4)	(0.5)
100	(0.3)	(0.2)	0.0	1.1

Table 4.5 Percentage change in rms for winds from verification against observations from trial 3. Reductions in brackets.

WIND %RMS CHANGE (TRIAL-OPERATIONAL)
STATISTICS FOR AREA 300
VERIFICATION AGAINST OBSERVATIONS

	T+0	T+24	T+48	T+72
850	(0.4)	(3.5)	(2.8)	(1.8)
700	0.2	(0.9)	0.2	0.4
500	(0.4)	(0.2)	(0.4)	(0.4)
400	(0.5)	(1.6)	(0.7)	(0.8)
300	(0.6)	(1.4)	(1.1)	(1.8)
250	0.1	(0.6)	(0.7)	(0.8)
200	0.9	0.2	(0.1)	0.7
100	(0.1)	0.3	(1.4)	(2.0)

WIND %RMS CHANGE (TRIAL-OPERATIONAL)
STATISTICS FOR AREA 400
VERIFICATION AGAINST OBSERVATIONS

	T+0	T+24	T+48	T+72
850	(0.5)	0.4	1.2	0.2
700	(0.1)	(0.4)	1.2	0.1
500	1.8	1.4	2.8	(0.4)
400	(1.9)	(0.2)	0.0	(1.4)
300	0.0	0.6	1.4	(0.4)
250	0.6	1.0	0.8	0.8
200	(0.6)	1.0	1.7	1.1
100	0.0	(0.7)	(0.5)	(2.4)

WIND - RMSVW % CHANGE (TRIAL-OPERATIONAL)
AREA 2
VERIFICATION AGAINST ANALYSES

	T+24	T+48	T+72
850	0.0	0.1	0.2
700	0.0	(0.2)	(0.2)
500	(0.3)	(0.4)	0.1
300	(0.2)	(0.1)	0.0
250	(0.3)	(0.9)	(0.6)
200	0.0	(0.6)	(1.2)
100	(0.8)	(0.6)	0.2

WIND - RMSVW % CHANGE (TRIAL-OPERATIONAL)
N.HEM
VERIFICATION AGAINST ANALYSES

	T+24	T+48	T+72
850	0.7	0.9	1.6
700	0.2	0.6	0.8
500	0.2	0.2	0.7
300	0.6	0.4	1.1
250	0.6	(0.2)	0.5
200	0.4	(0.4)	(0.1)
100	0.2	0.0	0.4

WIND - RMSVW % CHANGE (TRIAL-OPERATIONAL)
TROPICS
VERIFICATION AGAINST ANALYSES

	T+24	T+48	T+72
850	(4.2)	(3.4)	(2.2)
700	(2.0)	(2.0)	(2.0)
500	(1.6)	(2.1)	(1.6)
300	(1.1)	(1.3)	0.1
250	(1.1)	(1.1)	(0.6)
200	(1.3)	(1.1)	(1.0)
100	0.0	(1.1)	(1.5)

WIND - RMSVW % CHANGE (TRIAL-OPERATIONAL)
S.HEM
VERIFICATION AGAINST ANALYSES

	T+24	T+48	T+72
850	0.5	0.6	0.5
700	0.4	0.1	(0.6)
500	0.5	0.0	(0.8)
300	(0.3)	(0.9)	(0.6)
250	(0.6)	(1.1)	(0.6)
200	(0.3)	(0.7)	(0.7)
100	(0.2)	(0.9)	(1.8)

Table 4.6 Percentage change in rms for winds from verification against analyses from trial 3. Reductions in brackets.

REL HUM %RMS CHANGE (TRIAL-OPERATIONAL)
STATISTICS FOR AREA 2
VERIFICATION AGAINST OBSERVATIONS

	T+0	T+24	T+48	T+72
850	(0.5)	(0.3)	(0.5)	(0.2)
700	(0.7)	(1.5)	(2.8)	(1.5)
500	(0.2)	0.7	(0.2)	1.0

REL HUM %RMS CHANGE (TRIAL-OPERATIONAL)
STATISTICS FOR AREA 200
VERIFICATION AGAINST OBSERVATIONS

	T+0	T+24	T+48	T+72
850	0.2	0.3	0.1	0.1
700	(0.4)	(0.6)	(1.3)	(0.5)
500	(0.3)	0.6	(0.7)	(0.3)

Table 4.7 Percentage change in rms for relative humidity from verification against observations from trial 3. Reductions in brackets.

REL HUM %RMS CHANGE (TRIAL-OPERATIONAL)
STATISTICS FOR AREA 300
VERIFICATION AGAINST OBSERVATIONS

	T+0	T+24	T+48	T+72
850	(1.2)	(1.8)	(0.7)	(0.6)
700	(0.1)	(1.1)	(1.5)	(1.6)
500	(0.8)	(1.6)	(3.0)	(3.6)

REL HUM %RMS CHANGE (TRIAL-OPERATIONAL)
STATISTICS FOR AREA 400
VERIFICATION AGAINST OBSERVATIONS

	T+0	T+24	T+48	T+72
850	(1.3)	(1.0)	1.2	(0.2)
700	(0.4)	0.5	1.5	(0.2)
500	0.8	2.1	0.9	0.0

RELHUM RMSE % CHANGE (TRIAL-OPERATIONAL)
AREA 1
VERIFICATION AGAINST ANALYSES

	T+24	T+48	T+72
950	7.0	6.0	3.9
850	3.6	4.0	3.7
700	(0.2)	(0.2)	0.4
500	1.4	0.8	1.0

RELHUM RMSE % CHANGE (TRIAL-OPERATIONAL)
AREA 2
VERIFICATION AGAINST ANALYSES

	T+24	T+48	T+72
950	5.0	3.5	1.5
850	3.1	3.2	3.2
700	0.7	0.6	1.1
500	1.2	0.7	1.0

RELHUM RMSE % CHANGE (TRIAL-OPERATIONAL)
TROPICS
VERIFICATION AGAINST ANALYSES

	T+24	T+48	T+72
950	4.1	6.3	3.1
850	5.2	8.3	7.6
700	(1.6)	1.1	1.1
500	(5.5)	(6.8)	(6.4)

RELHUM RMSE % CHANGE (TRIAL-OPERATIONAL)
S.HEM
VERIFICATION AGAINST ANALYSES

	T+24	T+48	T+72
950	3.0	2.0	0.3
850	1.9	1.3	1.4
700	(0.6)	(0.2)	0.3
500	1.2	0.9	0.7

Table 4.8 Percentage change in rms for relative humidity from verification against analyses from trial 3. Reductions in brackets.

Table 4.9 Count of cases in which trial rms is better than or equal to the operational rms from verification against observations and against analyses from trial 3.

RMS RATIO (TRIAL/OPERATIONAL) ≤ 100% FOR ALL TIMES AND ALL LEVELS VERIFICATION AGAINST OBSERVATIONS

	TEMP max=32	HEIGHT max=32	WIND max=32	REL HUM max=12
AREA 2	19	15	19	10
N HEM	11	12	19	7
TROPICS	14	18	24	12
S HEM	19	12	15	7

max=no.times x no. levels
Third frozen physics trial 10/9/93-28/9/93

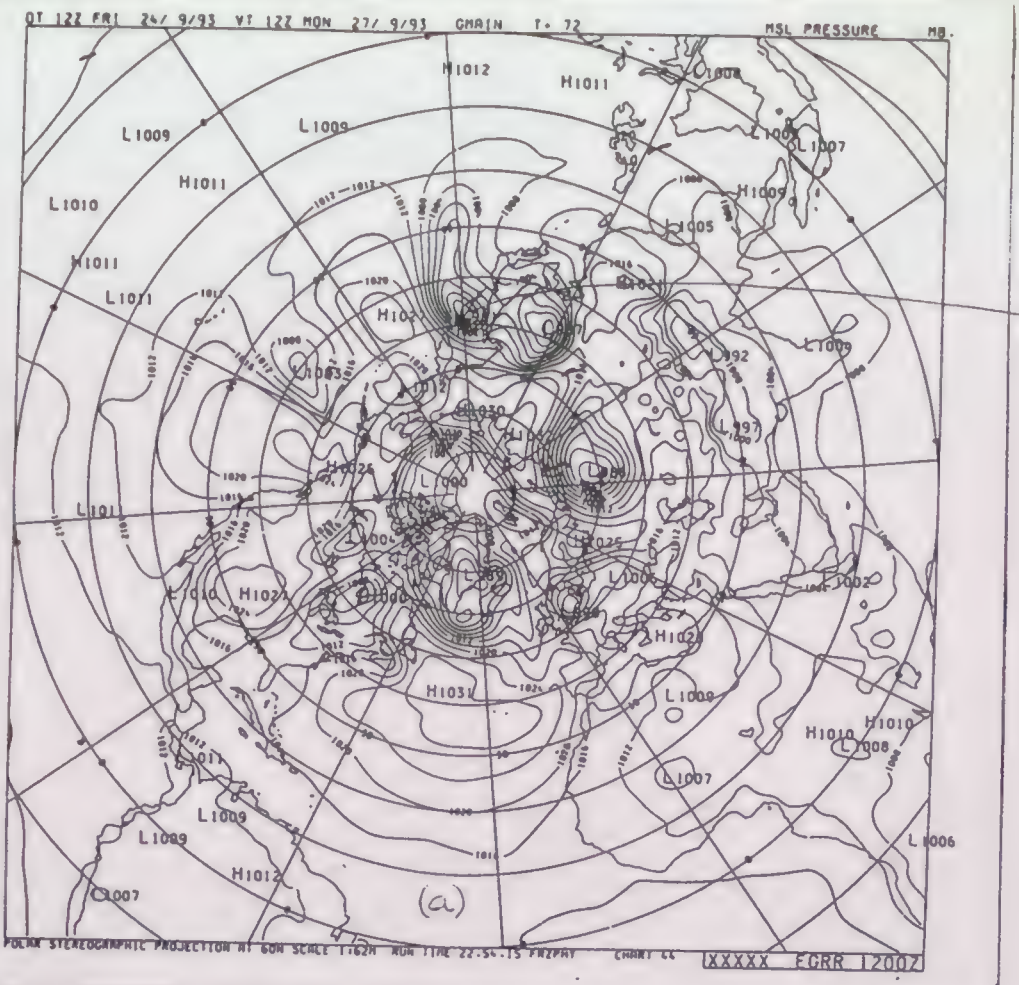
RMS RATIO (TRIAL/OPERATIONAL) ≤ 100% FOR ALL TIMES AND ALL LEVELS VERIFICATION AGAINST ANALYSES

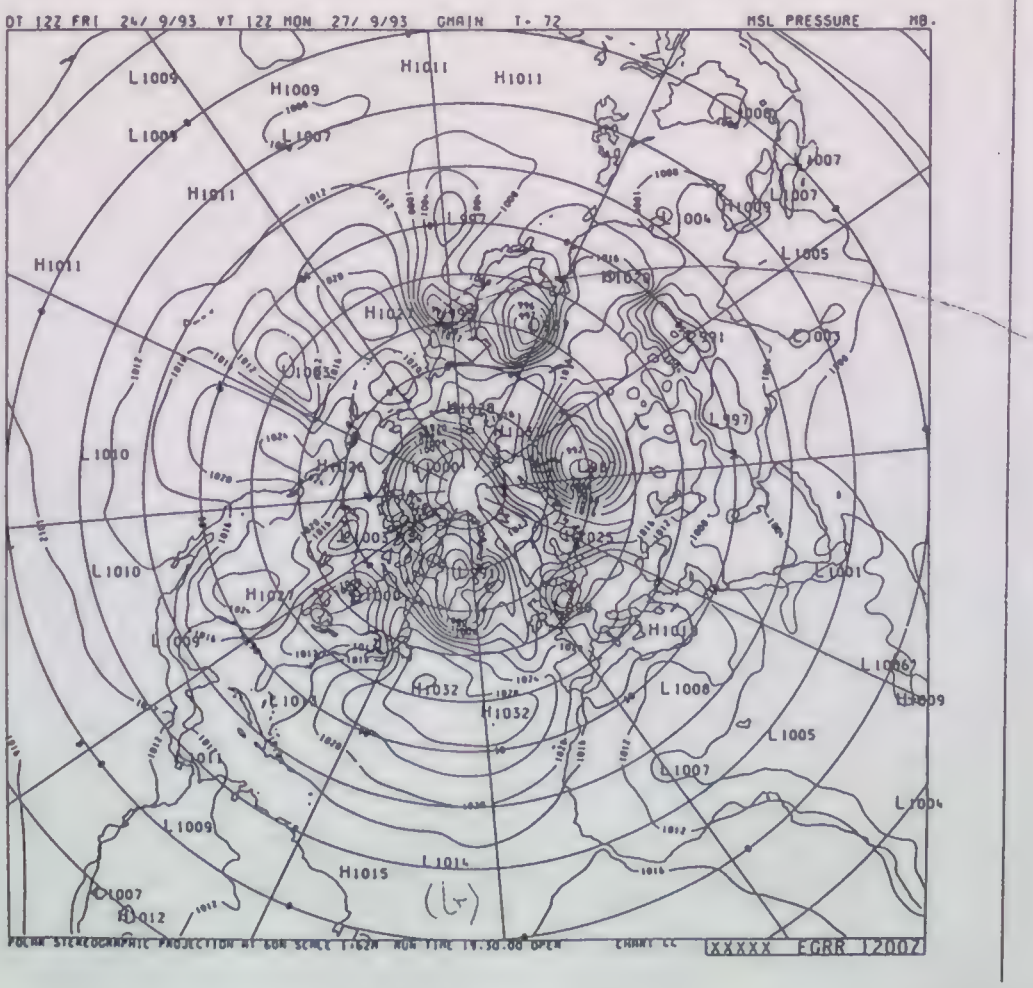
	TEMP max=24	HEIGHT max=24	WIND max=21	REL HUM max=12
AREA 2	14	13	16	2
N HEM	10	7	4	0
TROPICS	16	11	20	4
S HEM	21	21	15	2

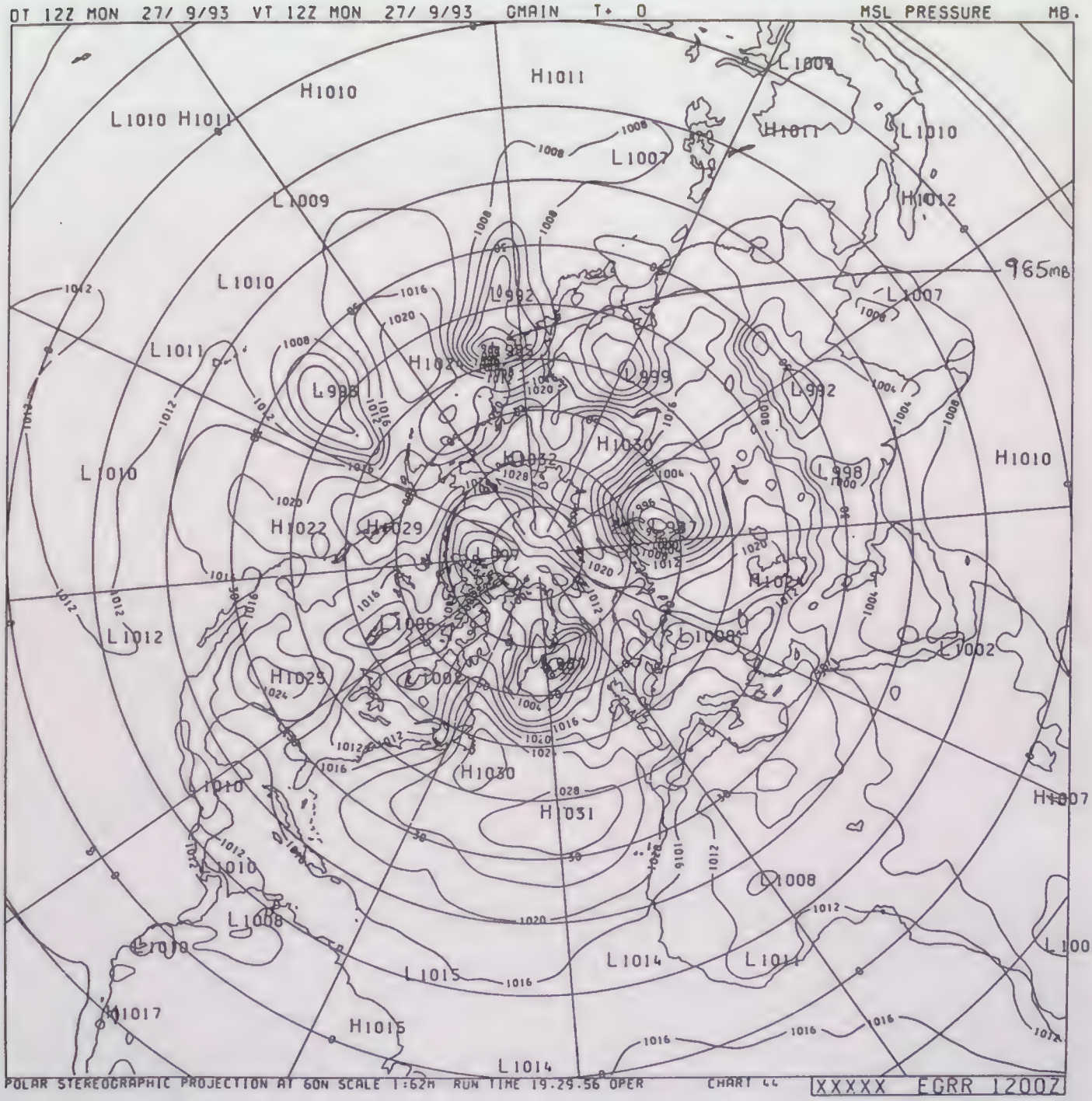
max=no.times x no. levels
Third frozen physics trial 10/9/93-28/9/93

5.01a Trial T+72 forecast mean sea level pressure verifying at 12Z 27/09/93.

5.01b As Figure 5.01a but for operational T+72 forecast.

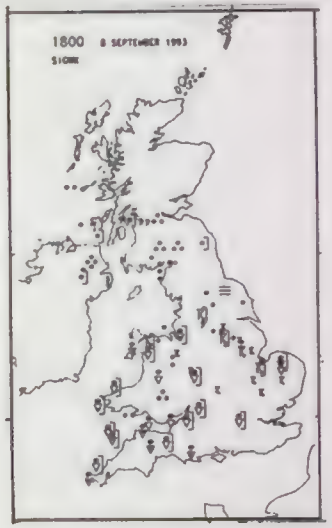


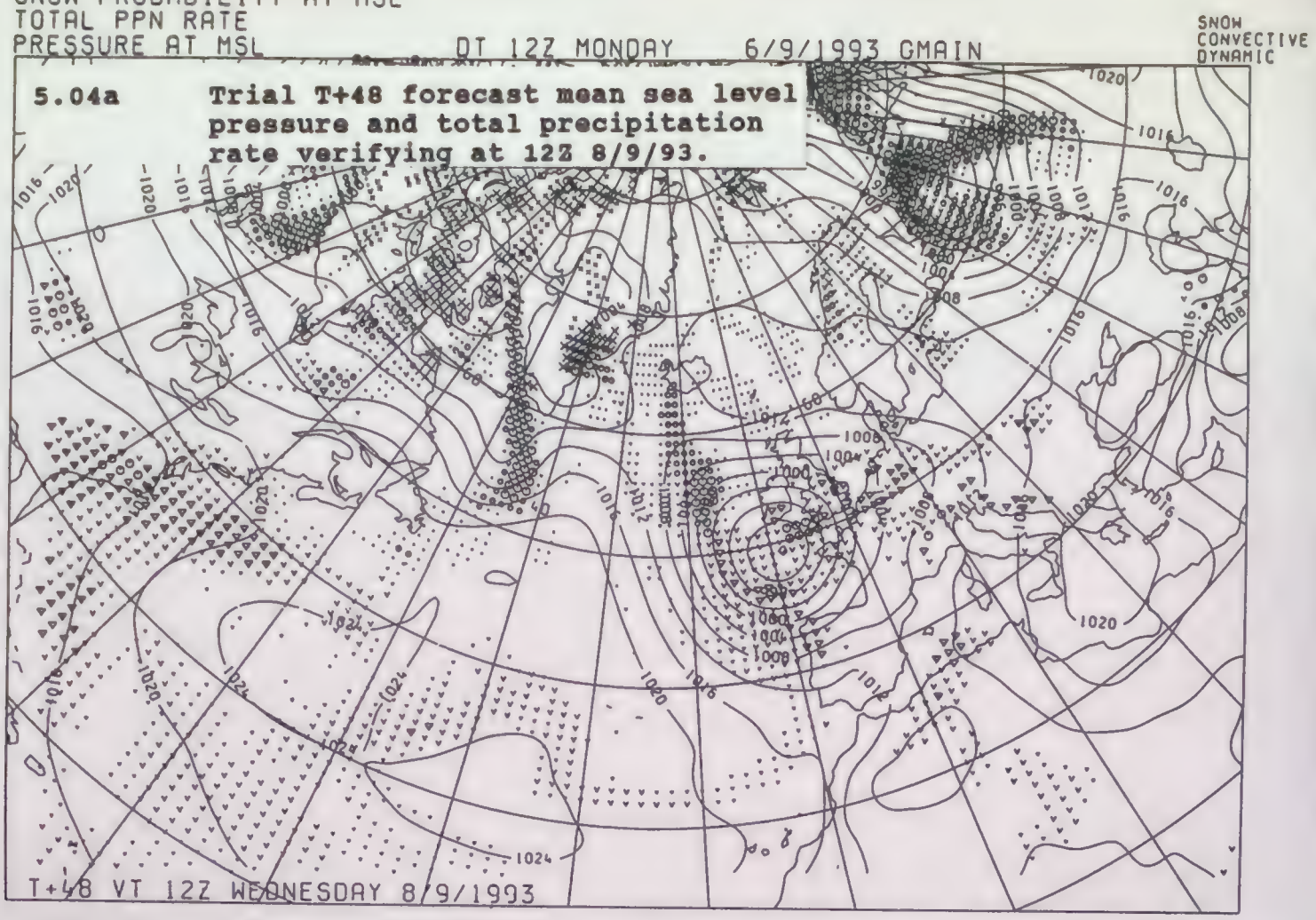


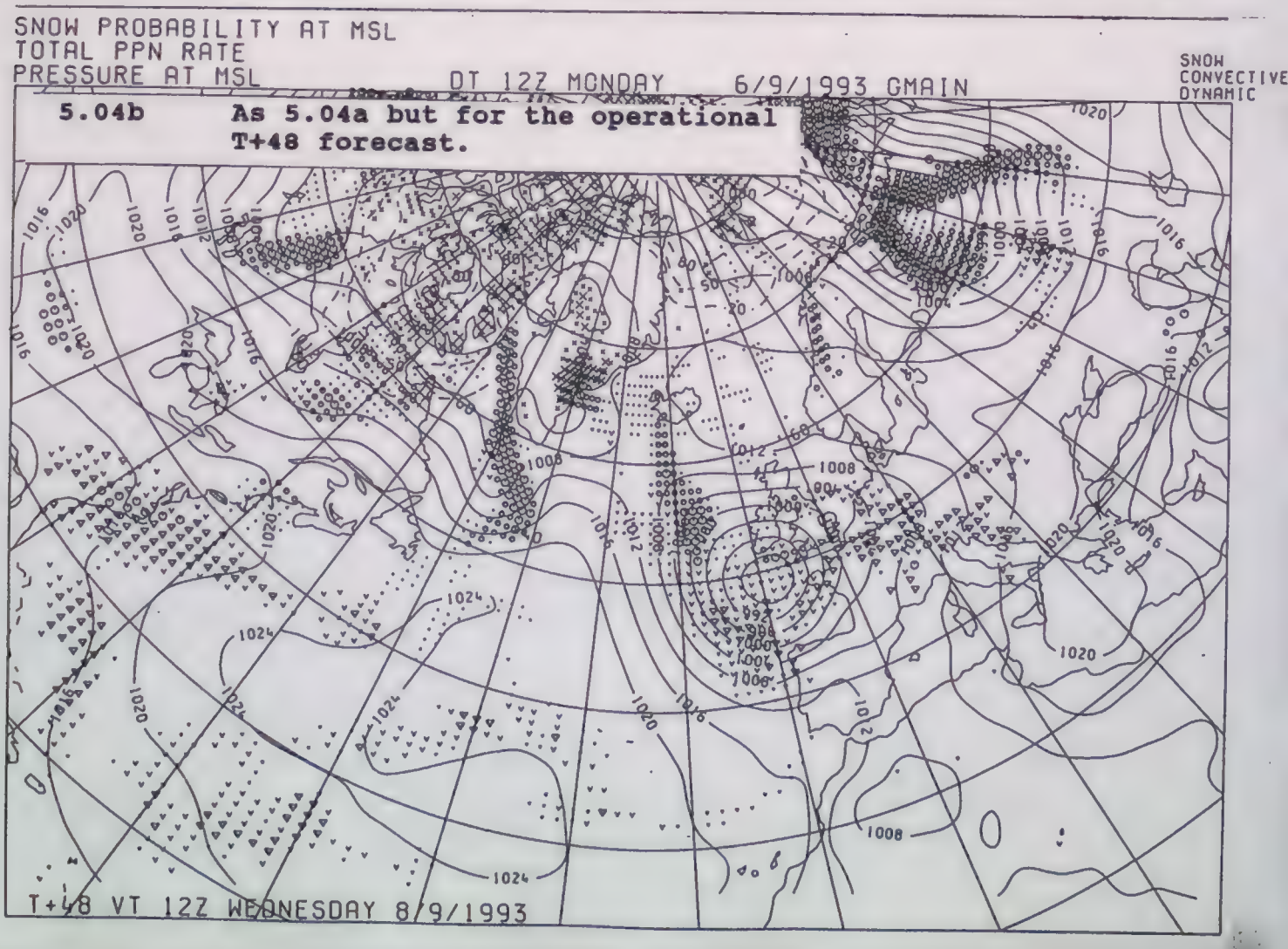


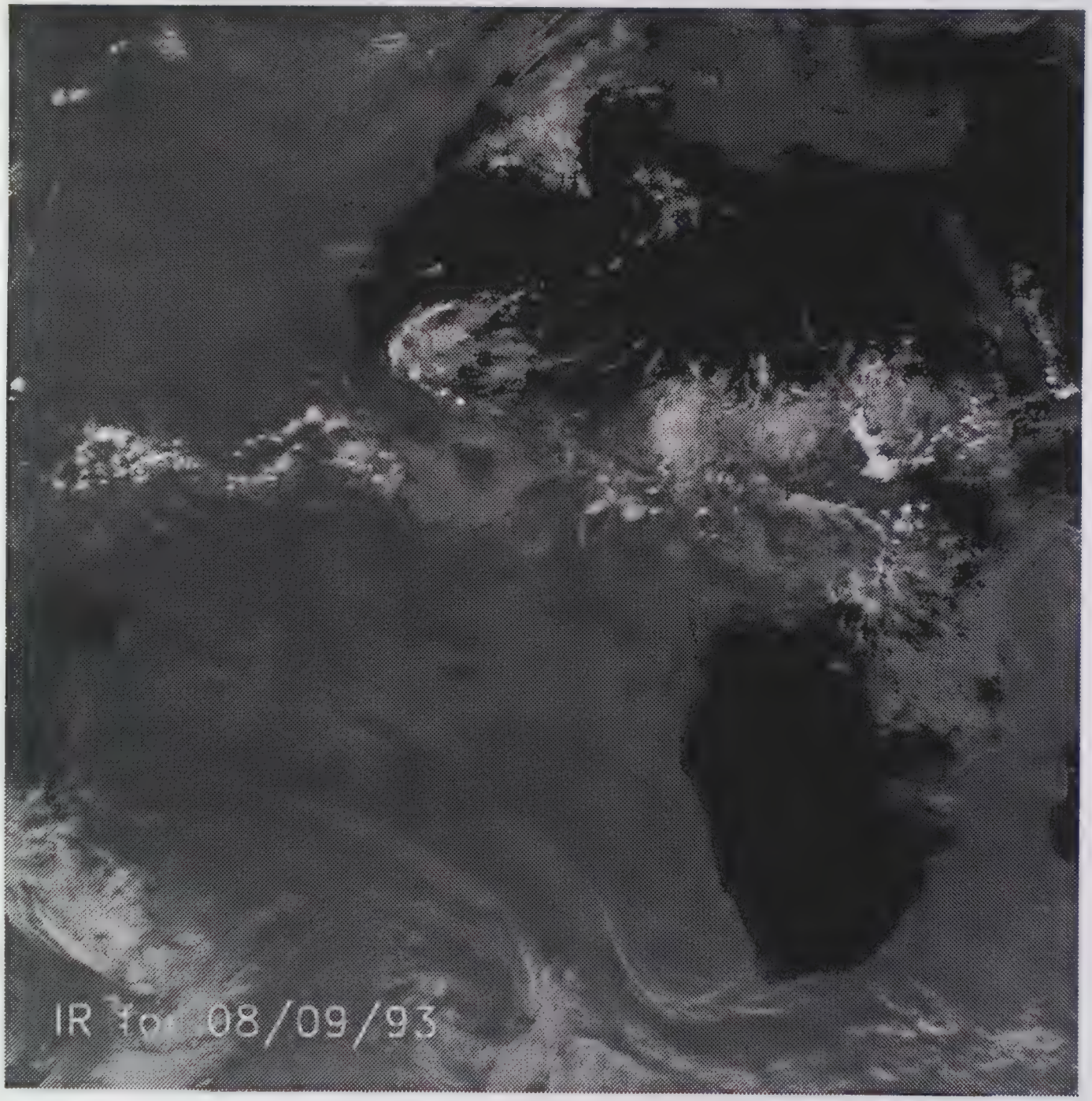
5.02 **Operational mean sea level pressure analysis for 12Z 27/09/93.**

5.03 **Modified radar composite over the U.K. at 12Z, and significant weather charts for 12Z and 18Z 8th September 1993.**



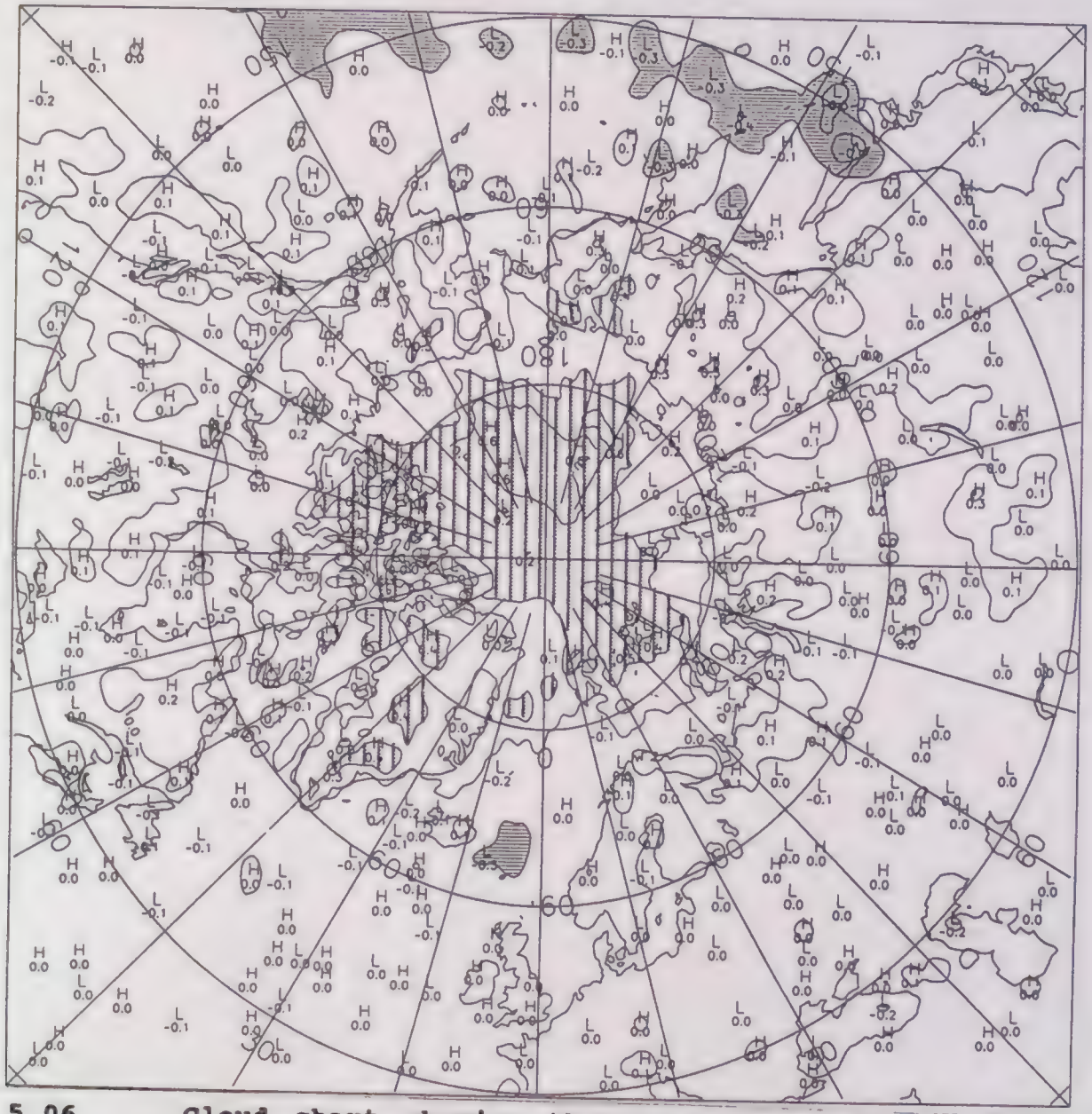

SNOW PROBABILITY AT MSL
TOTAL PPN RATE
PRESSURE AT MSL
DT 12Z MONDAY 6/9/1993 GMAIN
SNOW
CONVECTIVE
DYNAMIC
5.04a Trial T+48 forecast mean sea level pressure and total precipitation rate verifying at 12Z 8/9/93.
T+48 VT 12Z WEDNESDAY 8/9/1993


SNOW PROBABILITY AT MSL
TOTAL PPN RATE
PRESSURE AT MSL
DT 12Z MONDAY 6/9/1993 GMAIN
SNOW
CONVECTIVE
DYNAMIC
5.04b As 5.04a but for the operational T+48 forecast.
T+48 VT 12Z WEDNESDAY 8/9/1993



5.05 **Meteosat infrared satellite imagery over Africa at 12Z 8/9/93.**

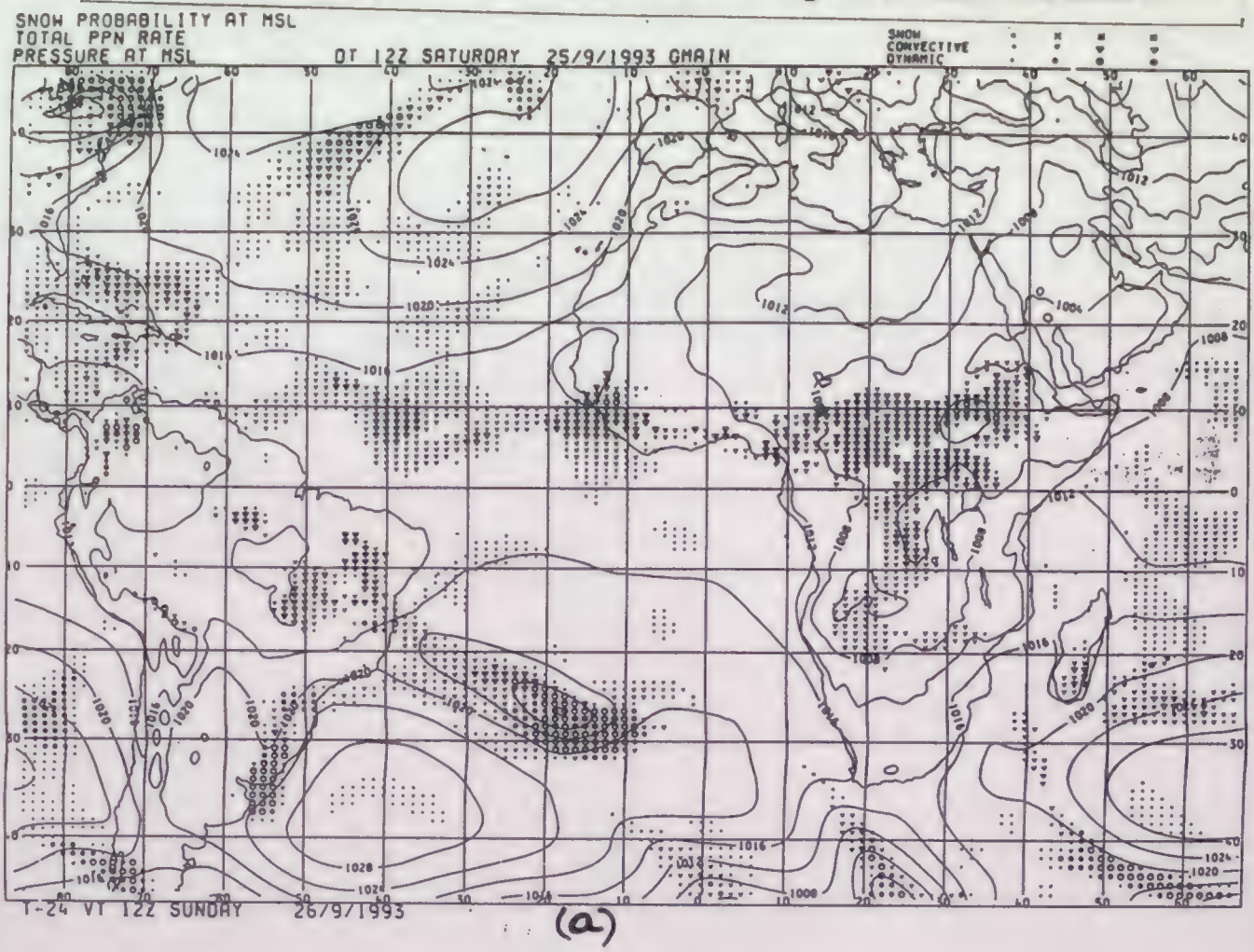
MEAN LOW CLOUD FPHY-OPER T+00
AVERAGE FROM 12.10Z ON 10/ 9/1993 DAY 253 TO 12.10Z ON 21/ 9/1993 DAY 264
LEVEL: ETA=0.9970



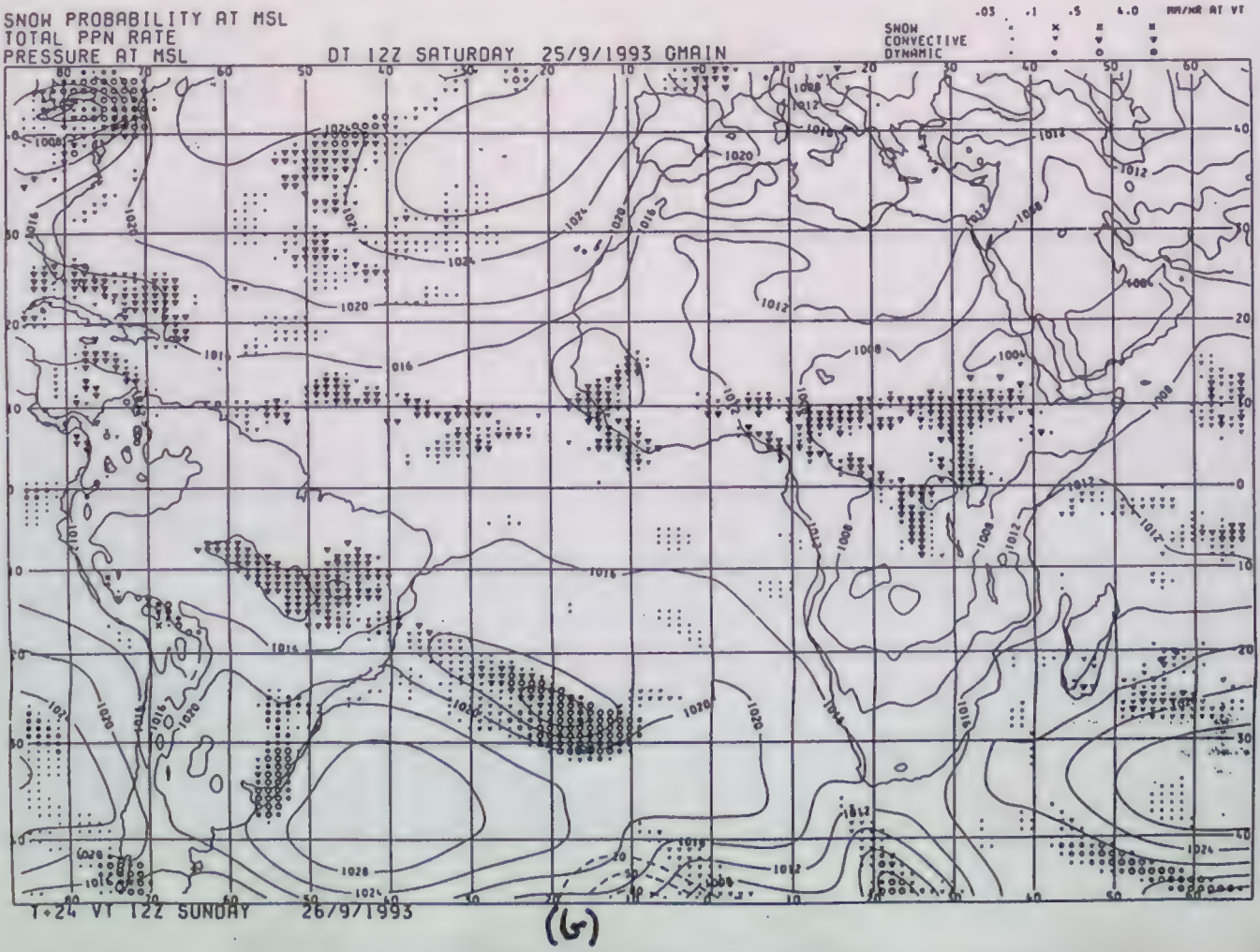
5.06 **Cloud chart showing the mean difference in level 1 cloud (ETA+0.997,trial-operational) in the Northern Hemisphere averaged from analyses over the period 12Z 10/09/93 to 12Z 21/09/92.**

5.07a T+24 rainfall forecast for Africa and South America from the trial model verifying at 12Z 26/09/93.

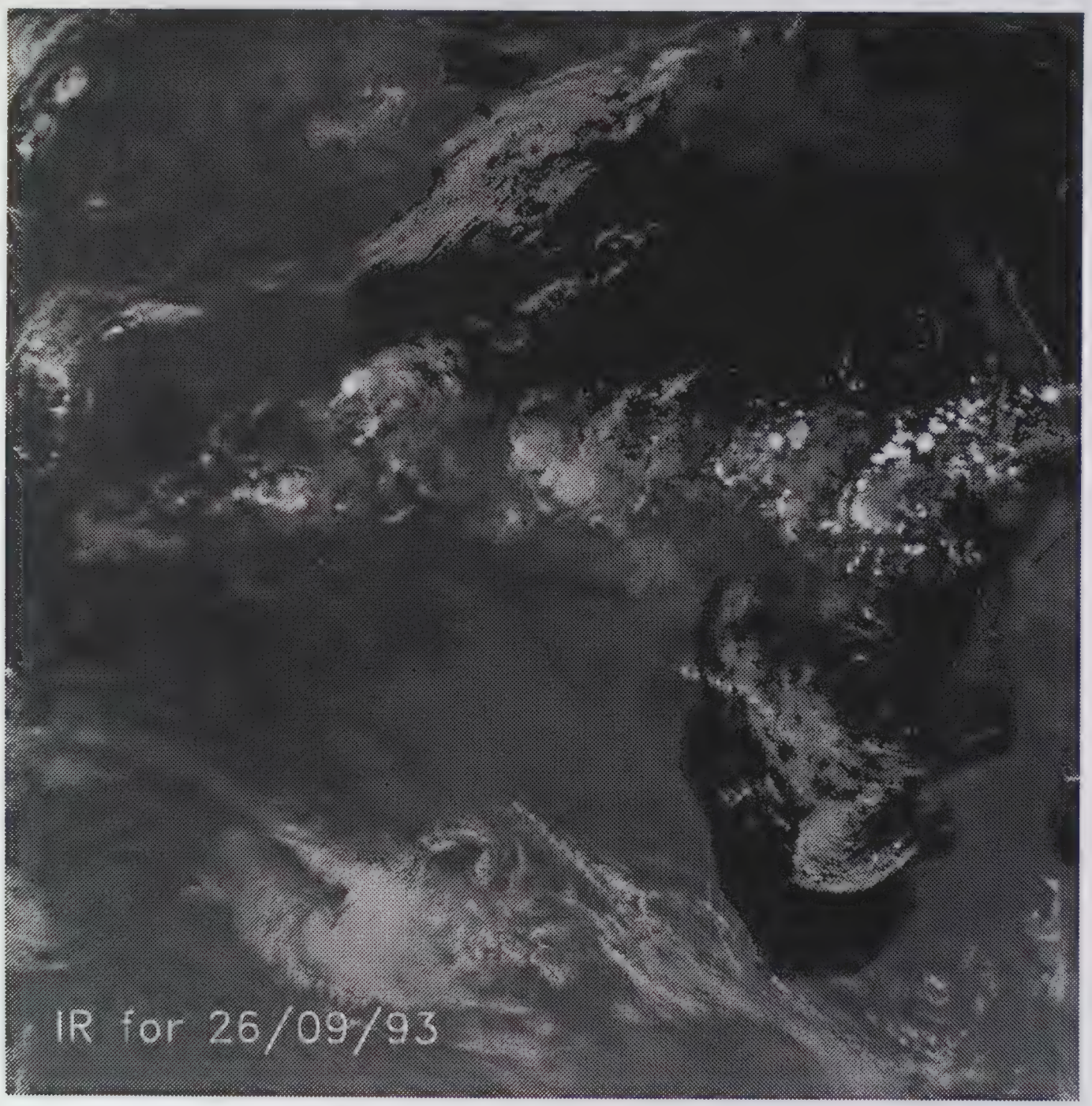
5.07b As Figure 5.07a but for the operational forecast.



(a)



(b)

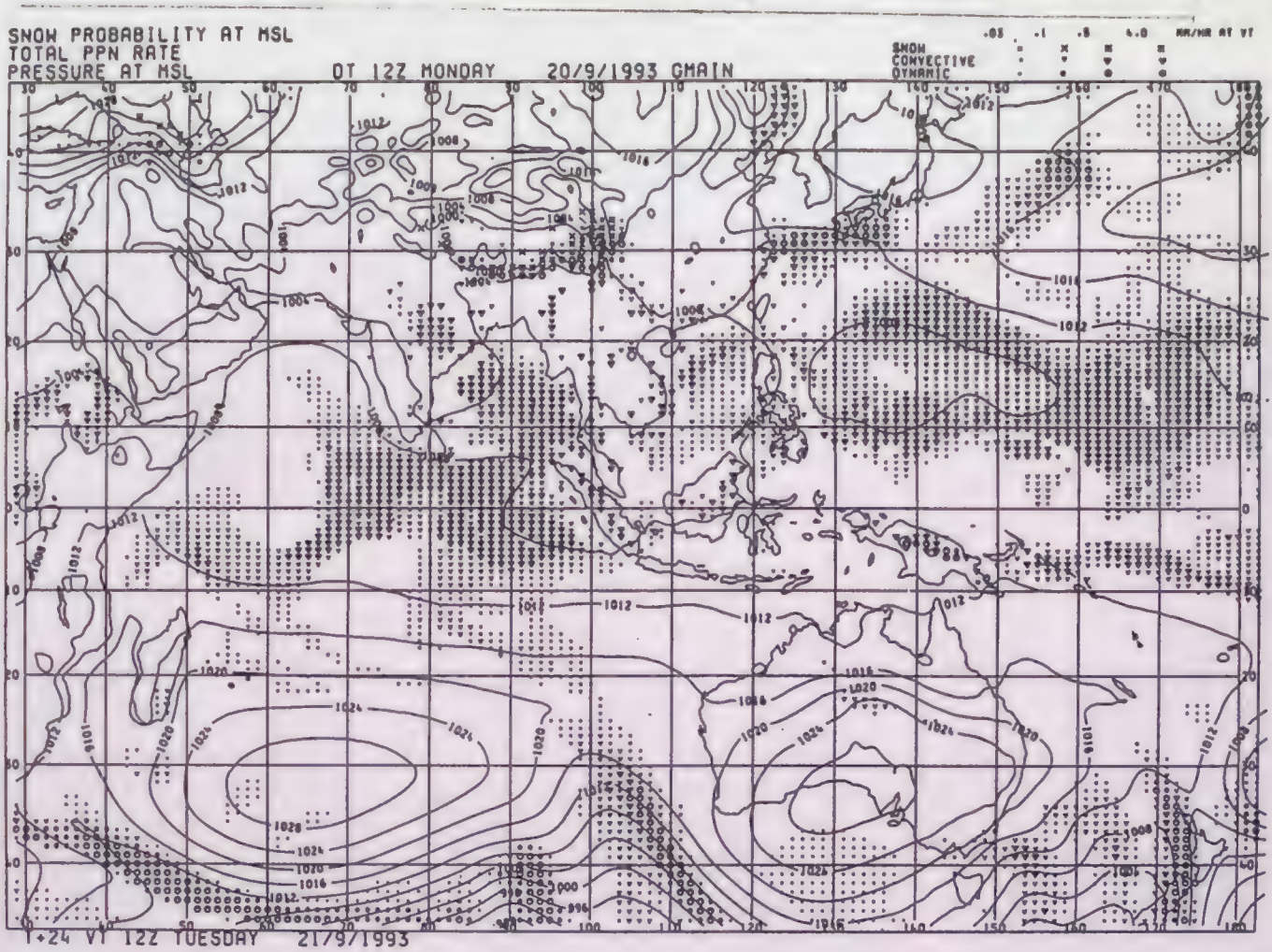


5.08 **Meteosat infrared satellite imagery over Africa at 12Z 26/09/93.**

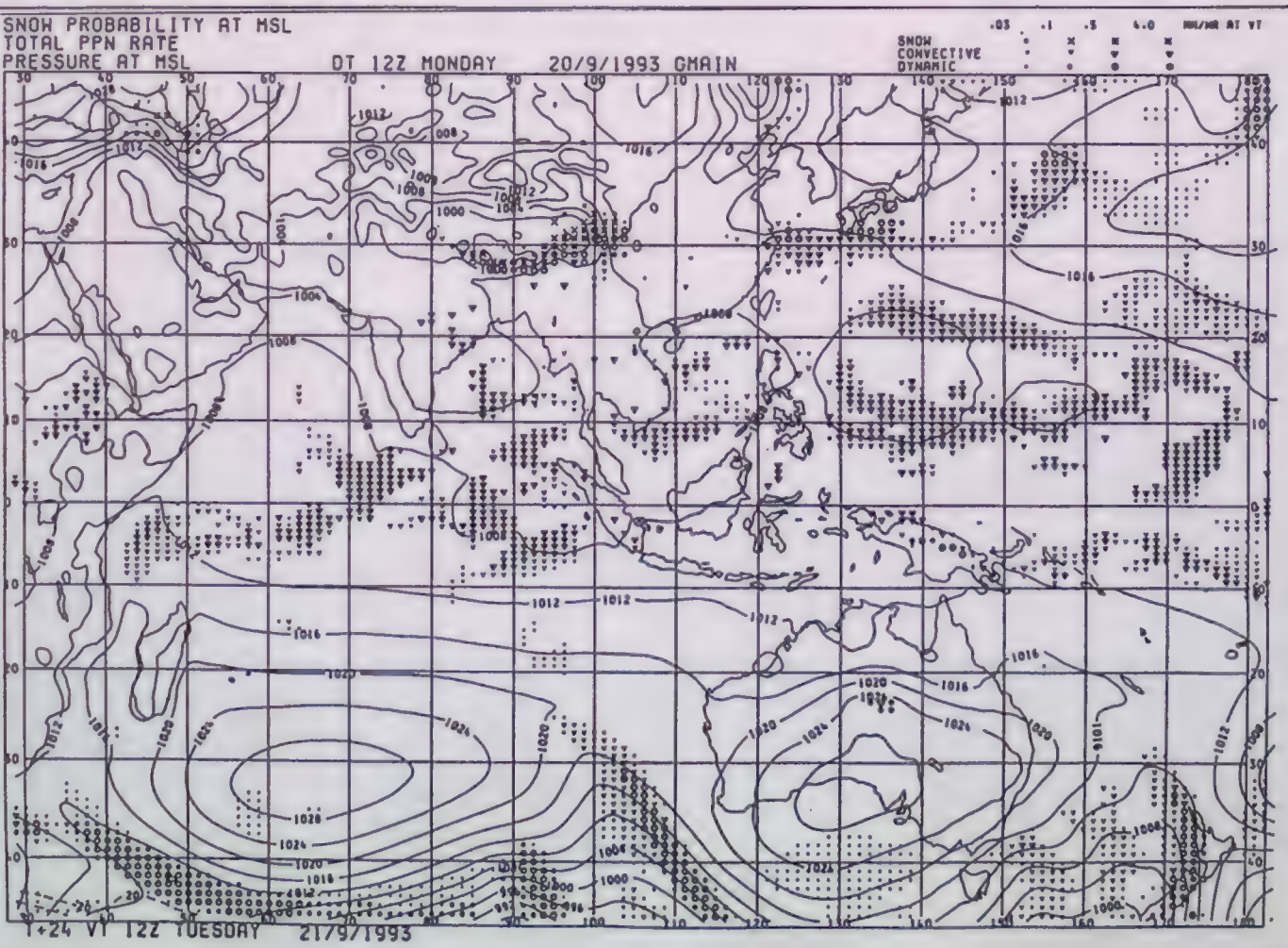
5.09a T+24 rainfall forecast for the Indian Ocean, South Pacific, Asia and Australia from the trial model verifying at 12Z 21/09/93.

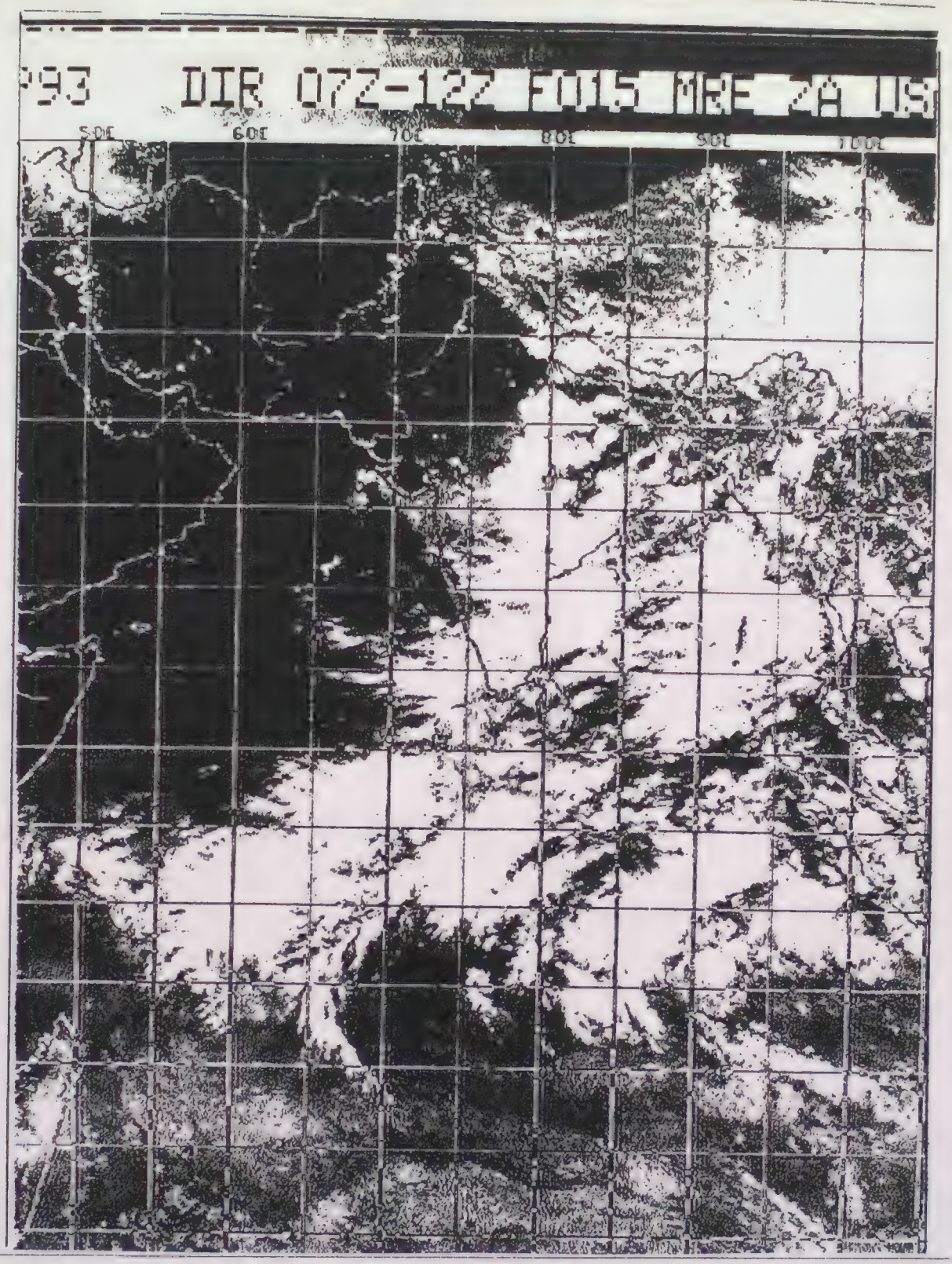
5.09b As Figure 5.09a but for the operational forecast.

(a)



(b)

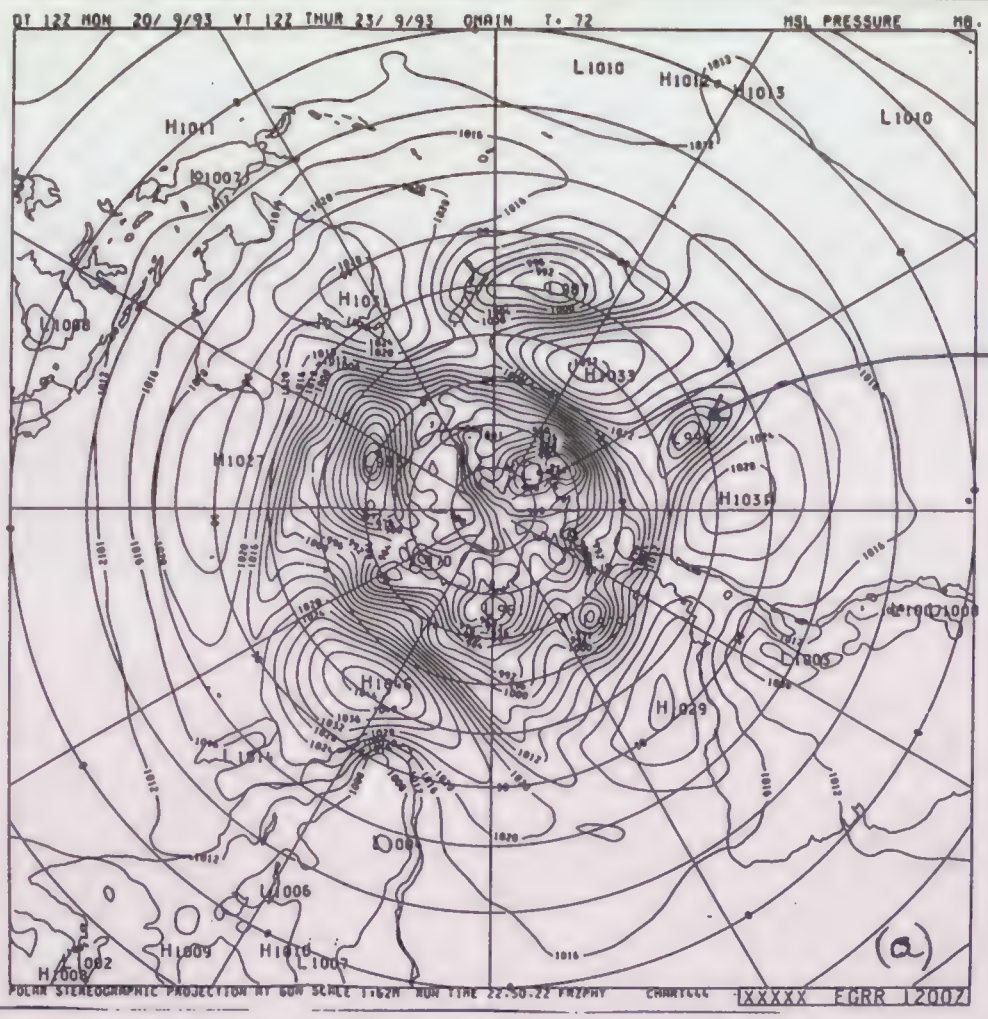




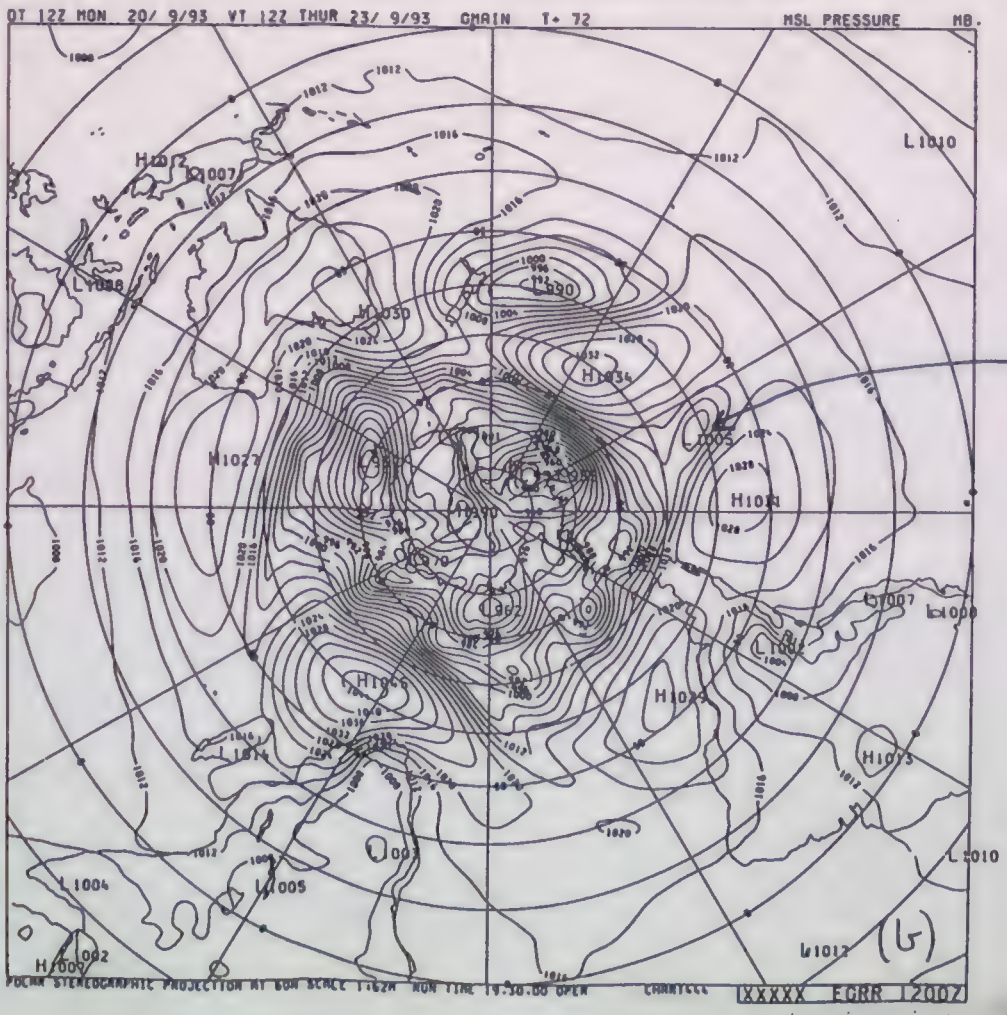
5.10 **NOAA-11 infrared satellite imagery over India at 12Z 21/09/93.**

5.11a Trial T+72 forecast mean sea level pressure for the Southern Hemisphere, verifying at 12Z 23/09/93

5.11b As Figure 5.11a but for the operational forecast.

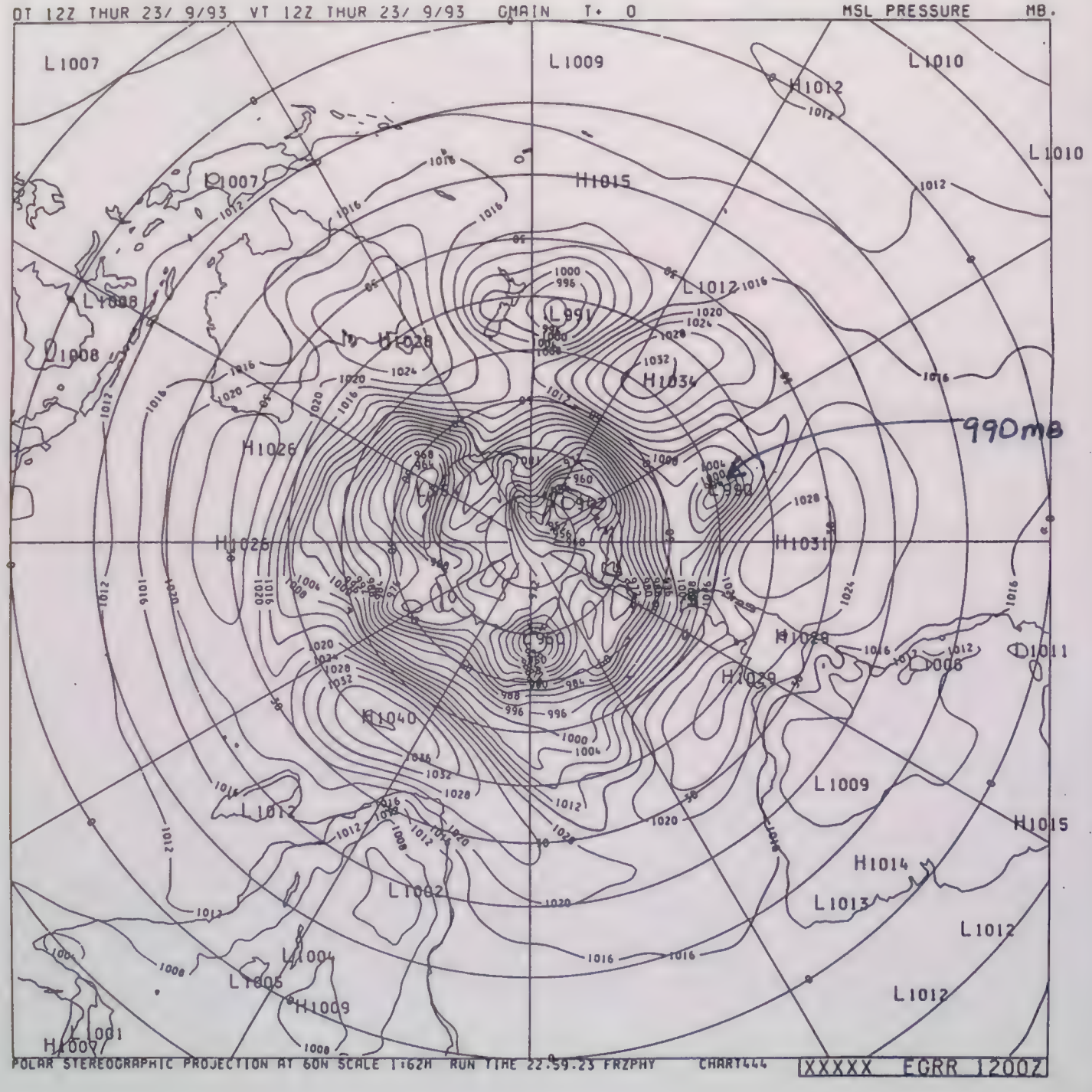


998 mb

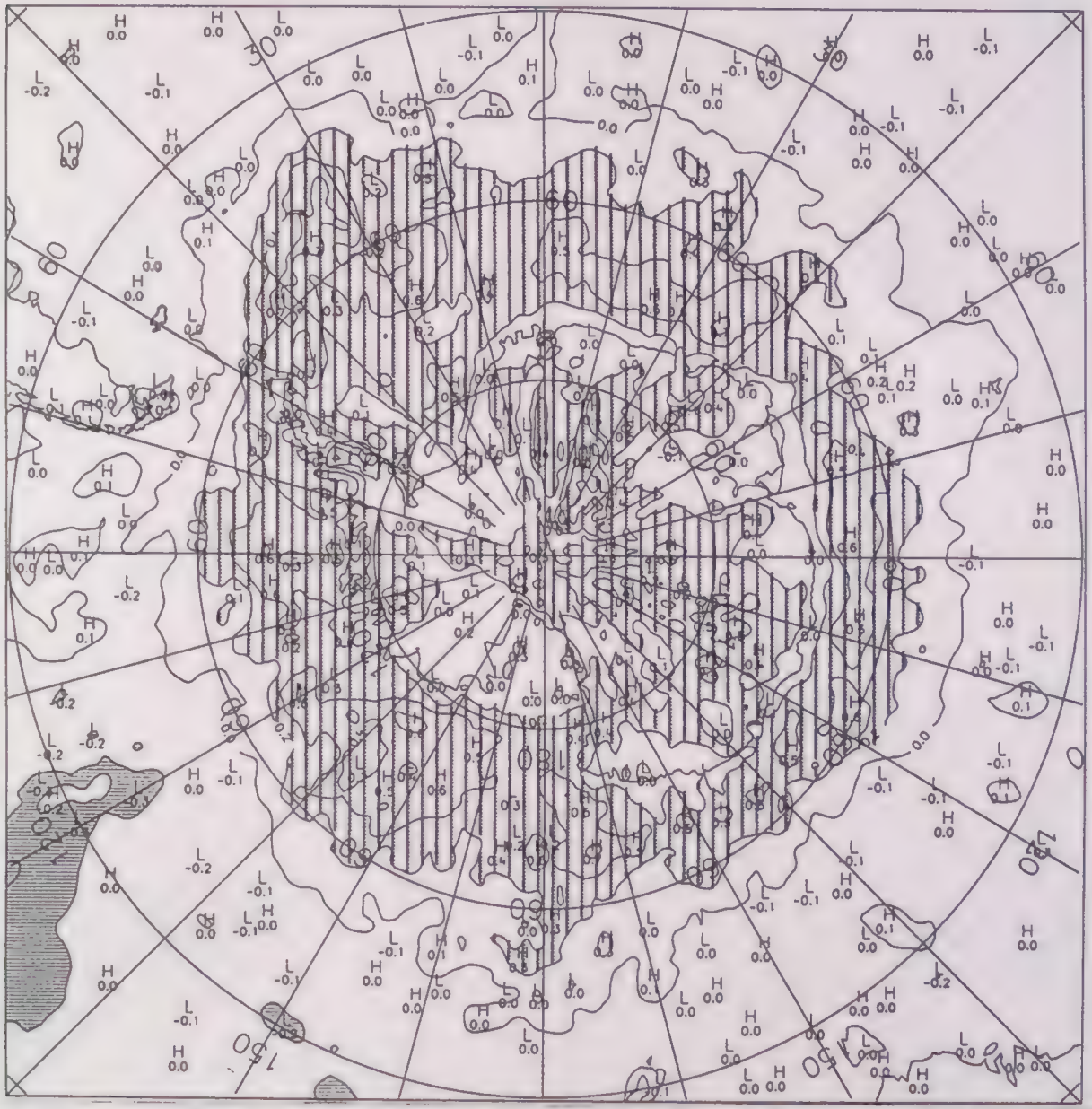


1005 mb

5.12 **Mean sea level pressure analysis for the Southern Hemisphere for 12Z 23/09/93 from the parallel suite.**



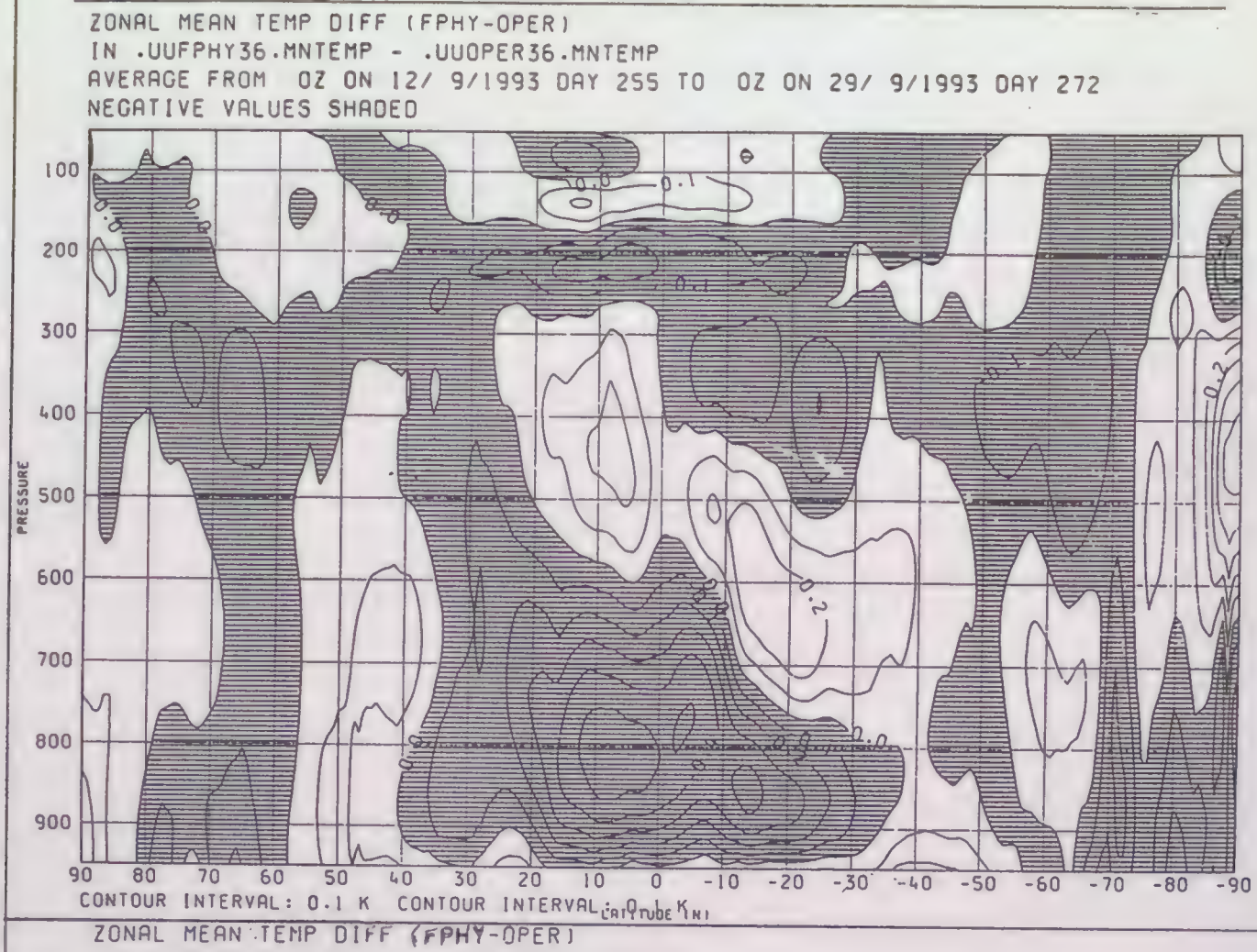
MEAN LOW CLOUD FPHY-OPER T+00
AVERAGE FROM 12.10Z ON 10/ 9/1993 DAY 253 TO 12.10Z ON 21/ 9/1993 DAY 264
LEVEL: ETA=0.9970

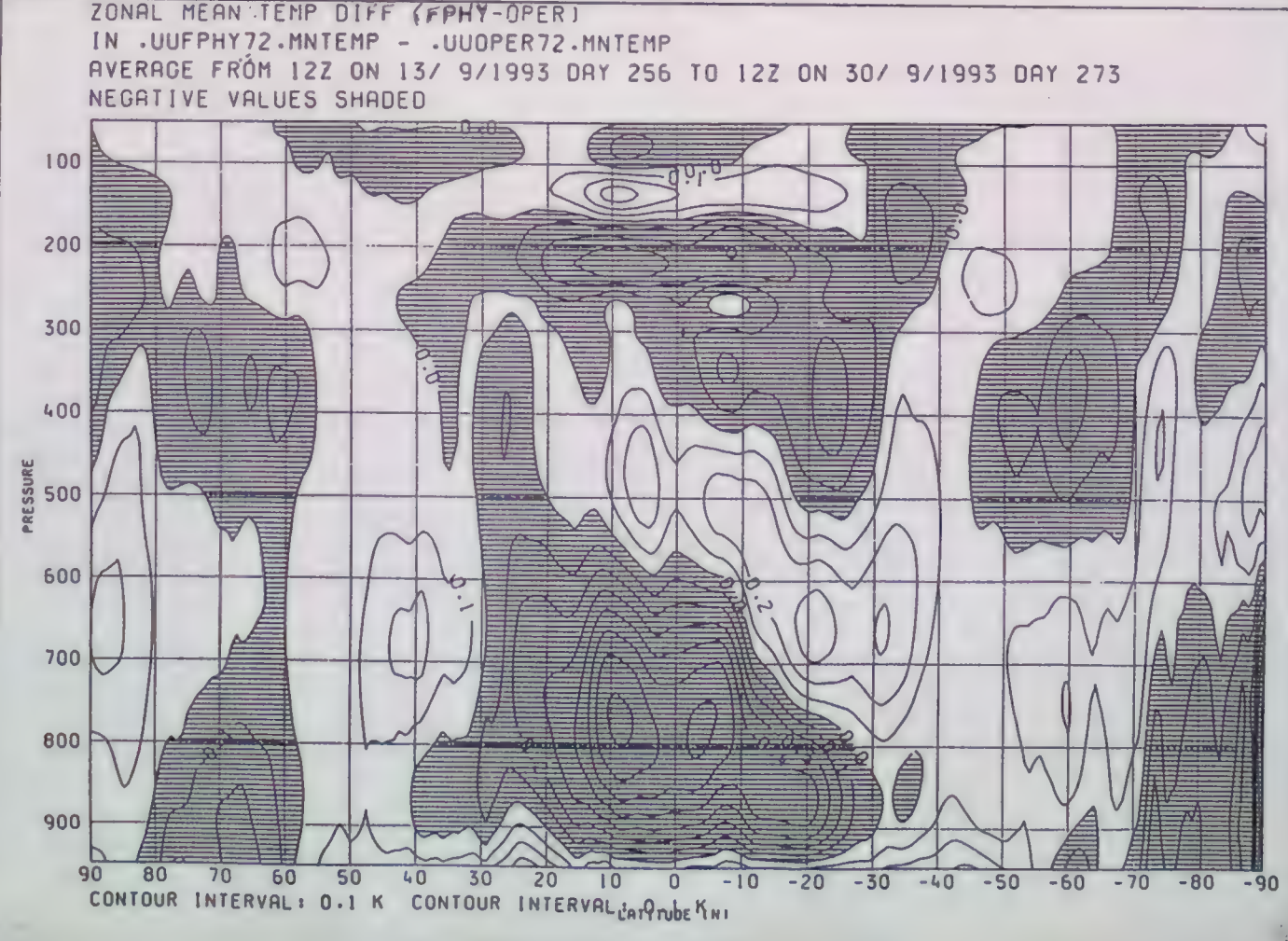


5.13 **Cloud chart showing the mean level 1 cloud differences (ETA=0.997,trial-operational) in the Southern Hemisphere averaged from analyses during the period 12z 10/09/93-21/09/93.**

5.14a Cross section showing zonal mean temperature differences (trial-operational) at 10 standard levels between 950mb and 50mb averaged from T+36 forecasts during the period 00Z 12/09/93 - 00Z 29/09/93.

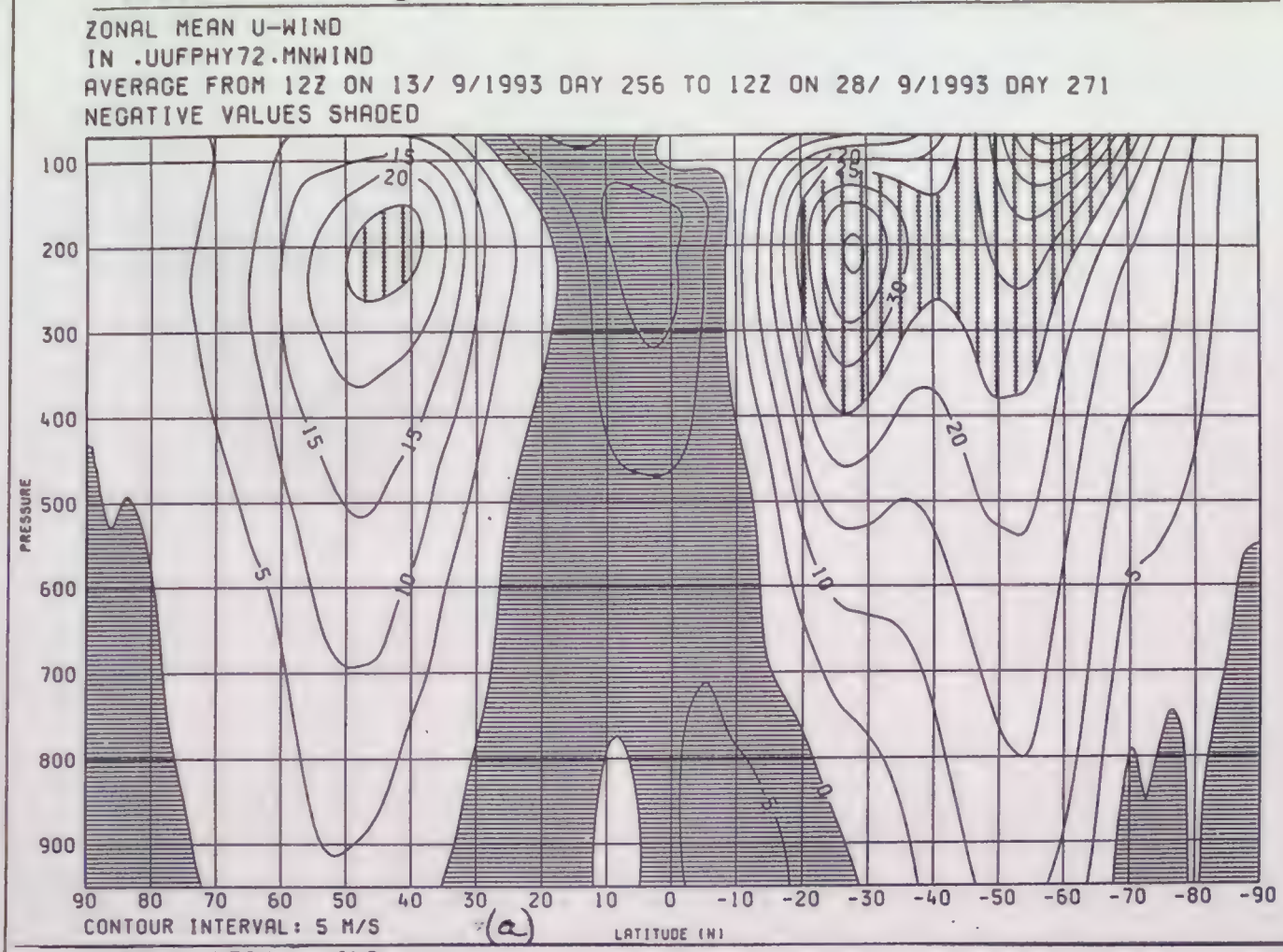
5.14b As Figure 5.14a but for T+72 forecasts averaged over the period 12Z 13/09/93 to 12Z 30/09/93.

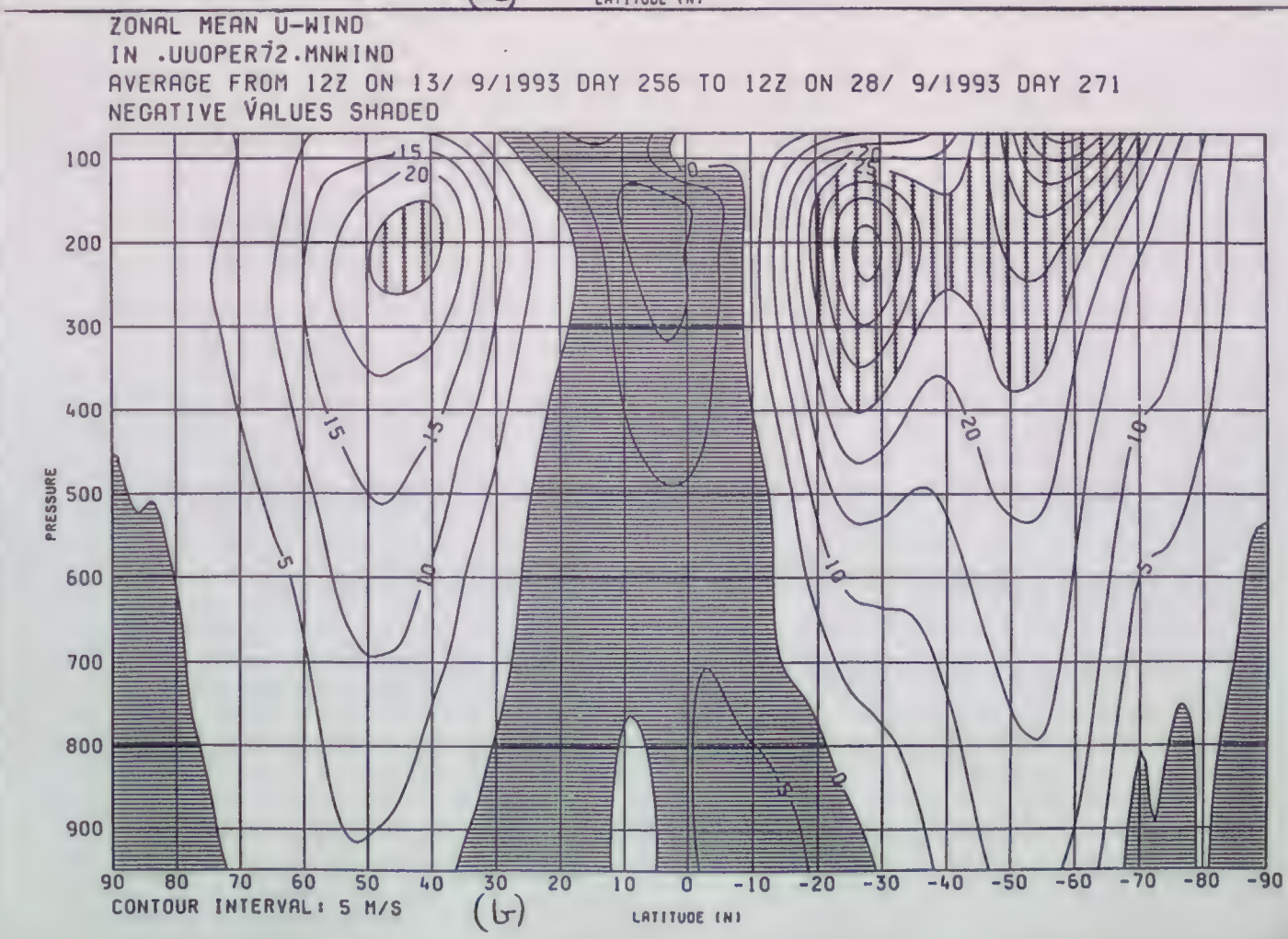




5.15a Cross section showing zonal mean "u" wind components at 10 standard levels between 950mb and 50mb averaged from T+72 trial forecasts during the period 12Z 13/09/92 to 12Z 28/09/93.

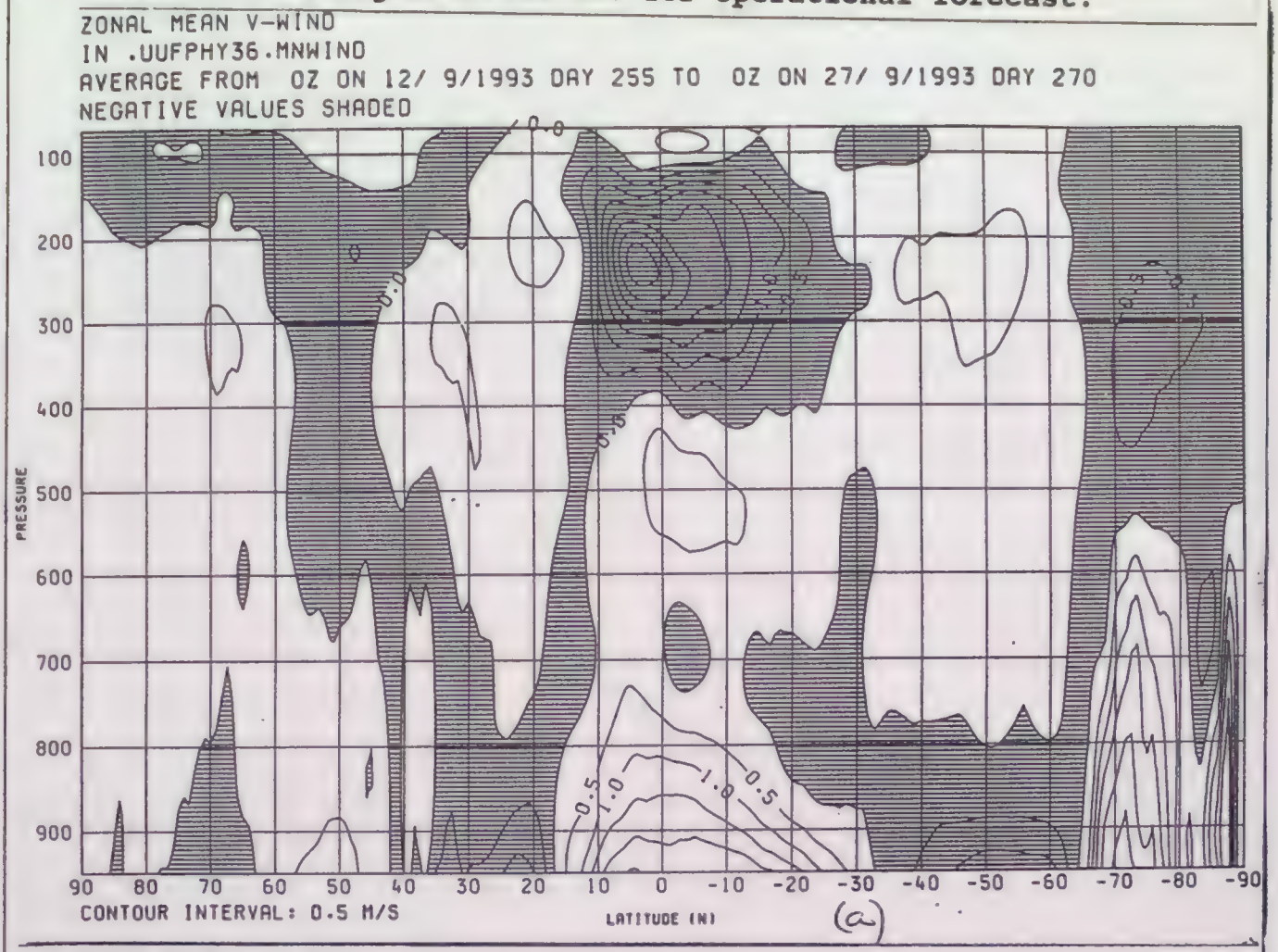
5.15b As Figure 5.15a but for operational forecasts.

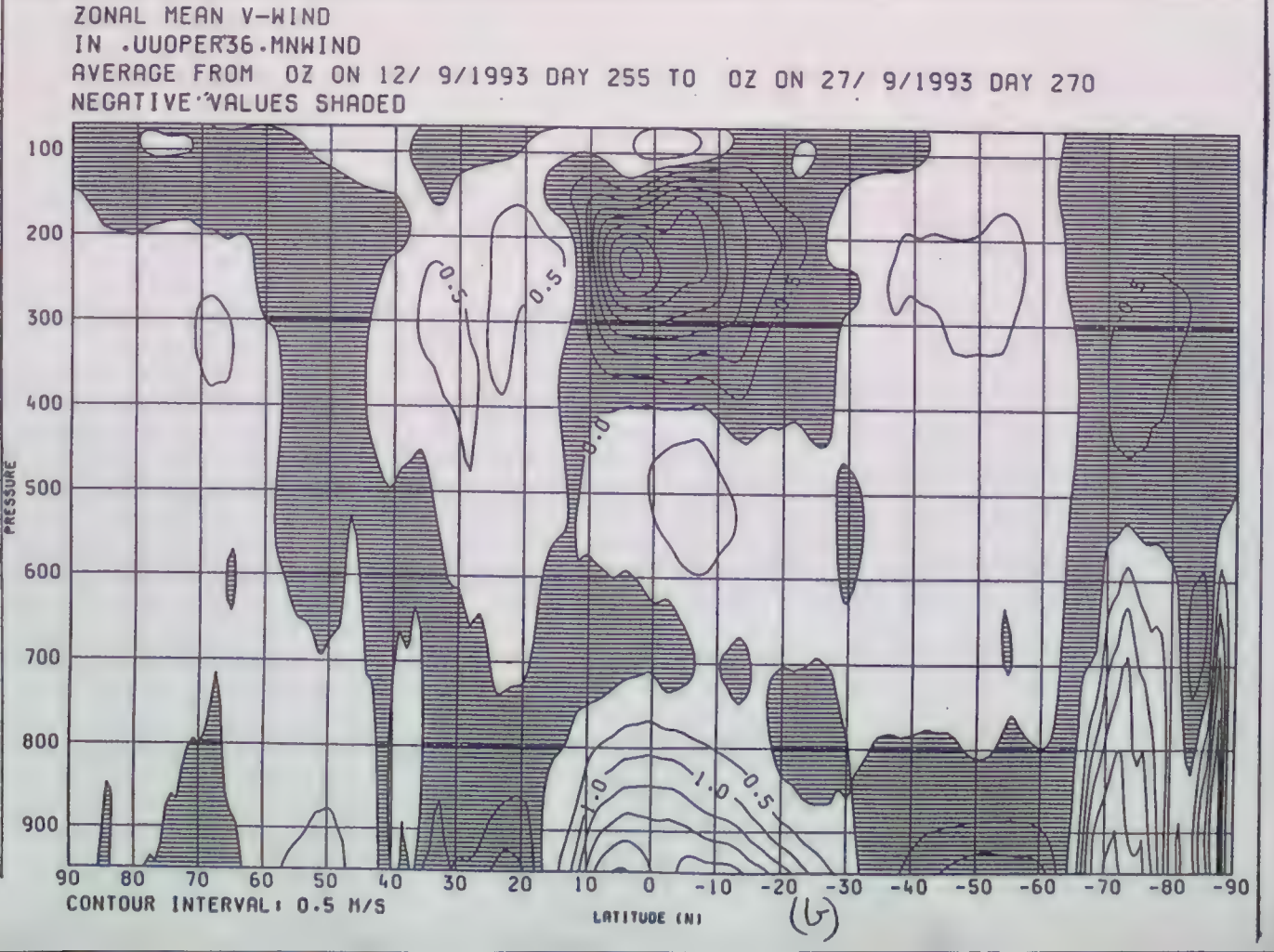




5.16a Cross section showing zonal mean "v" wind components at 10 standard levels between 950mb and 50mb from T+36 trial forecasts during the period 00Z 12/09/93 to 00Z 27/09/93.

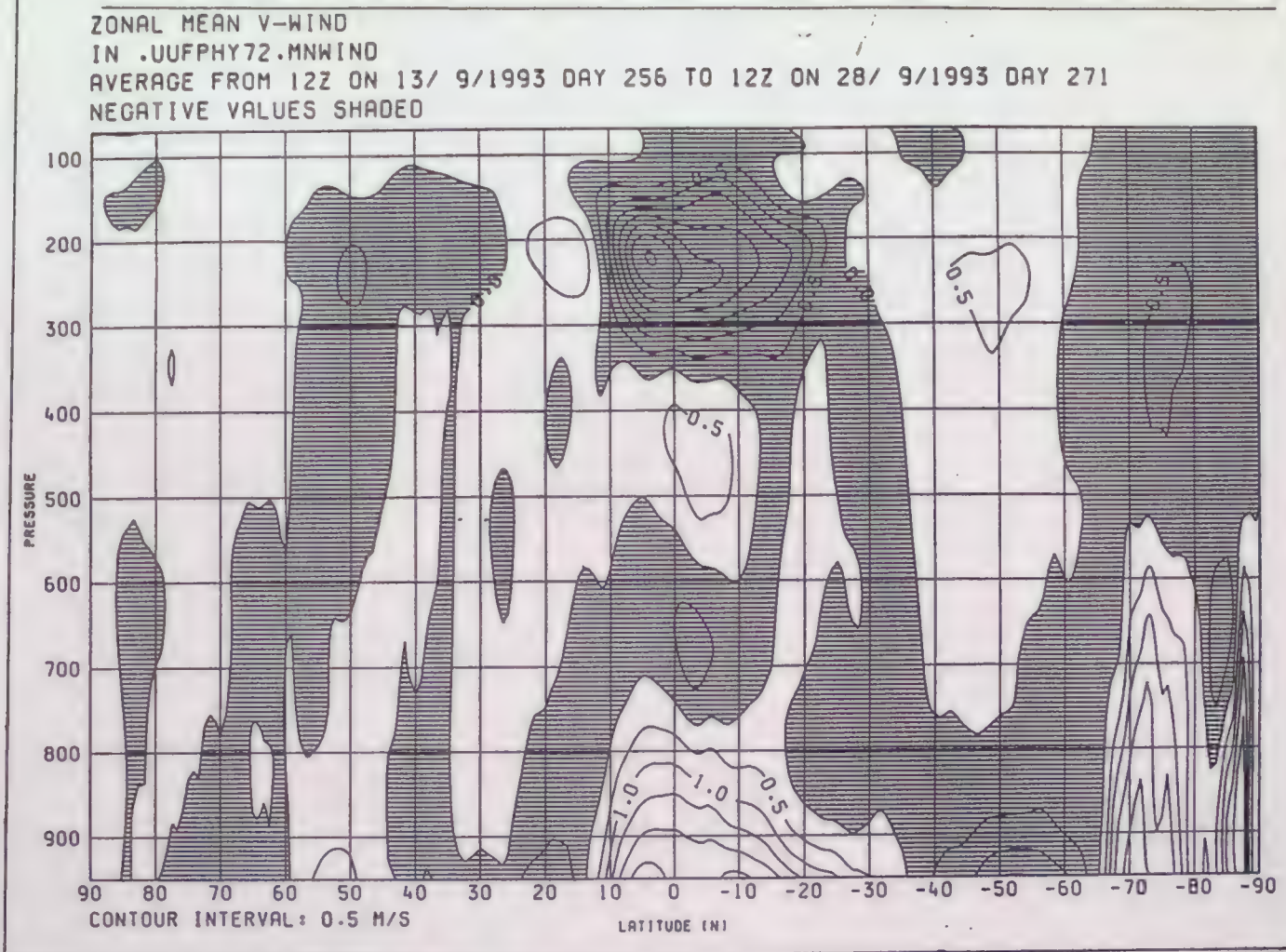
5.16b As Figure 5.16a but for operational forecast.

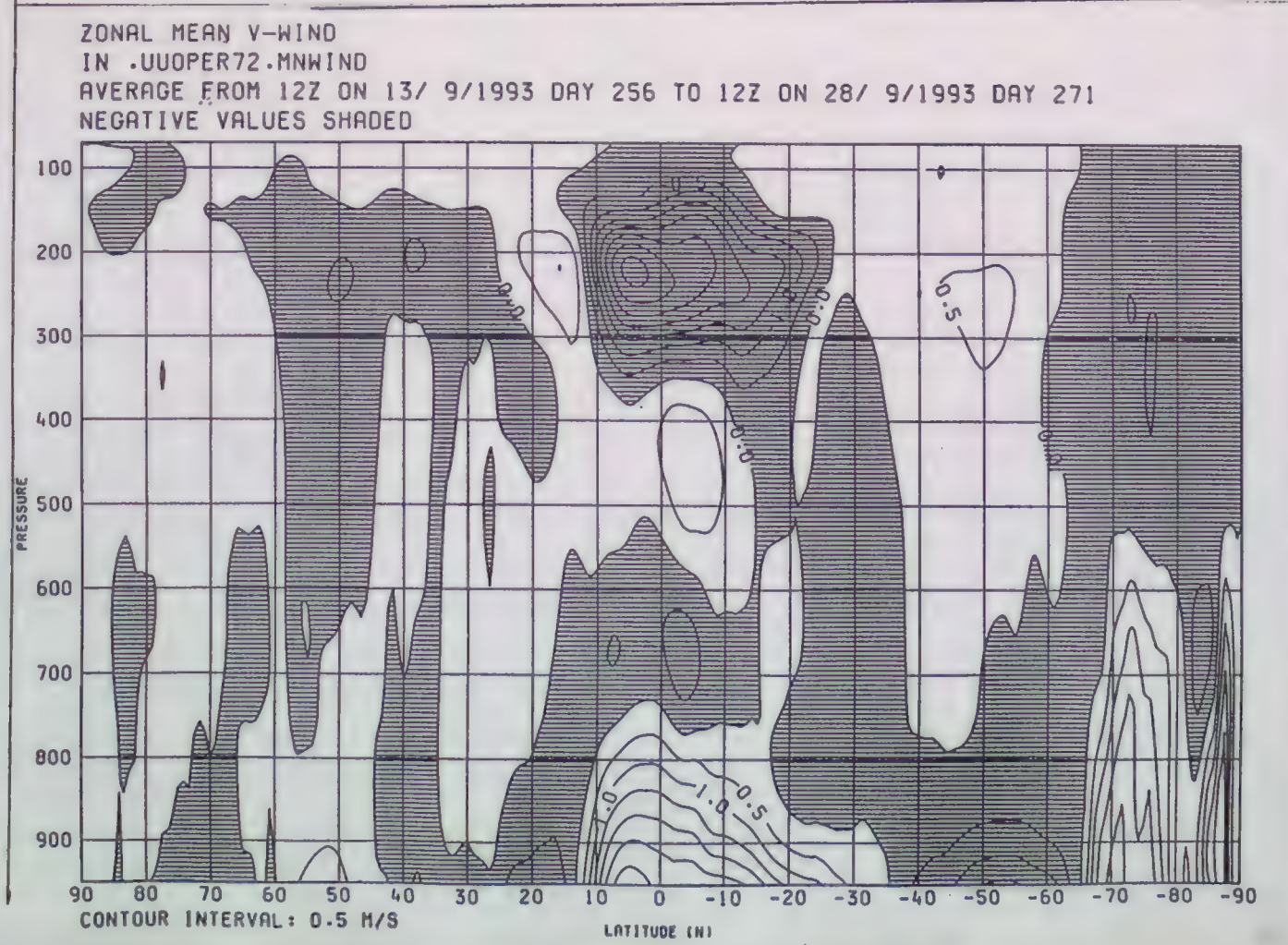




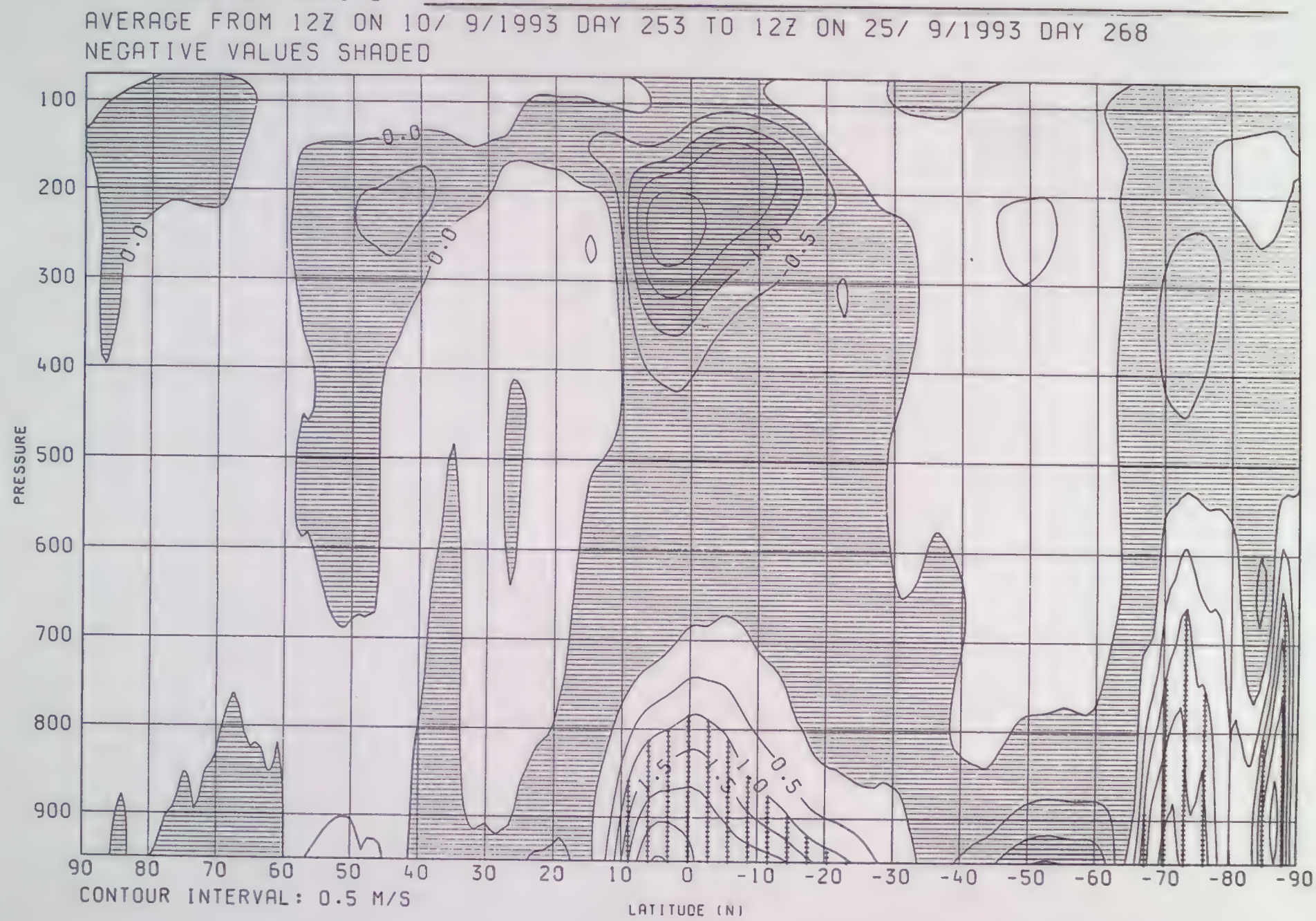
5.17a Cross section showing zonal mean "v" wind components at 10 standard levels between 950mb and 50mb from T+72 trial forecasts during the period 12Z 13/09/93 to 12Z 28/09/93.

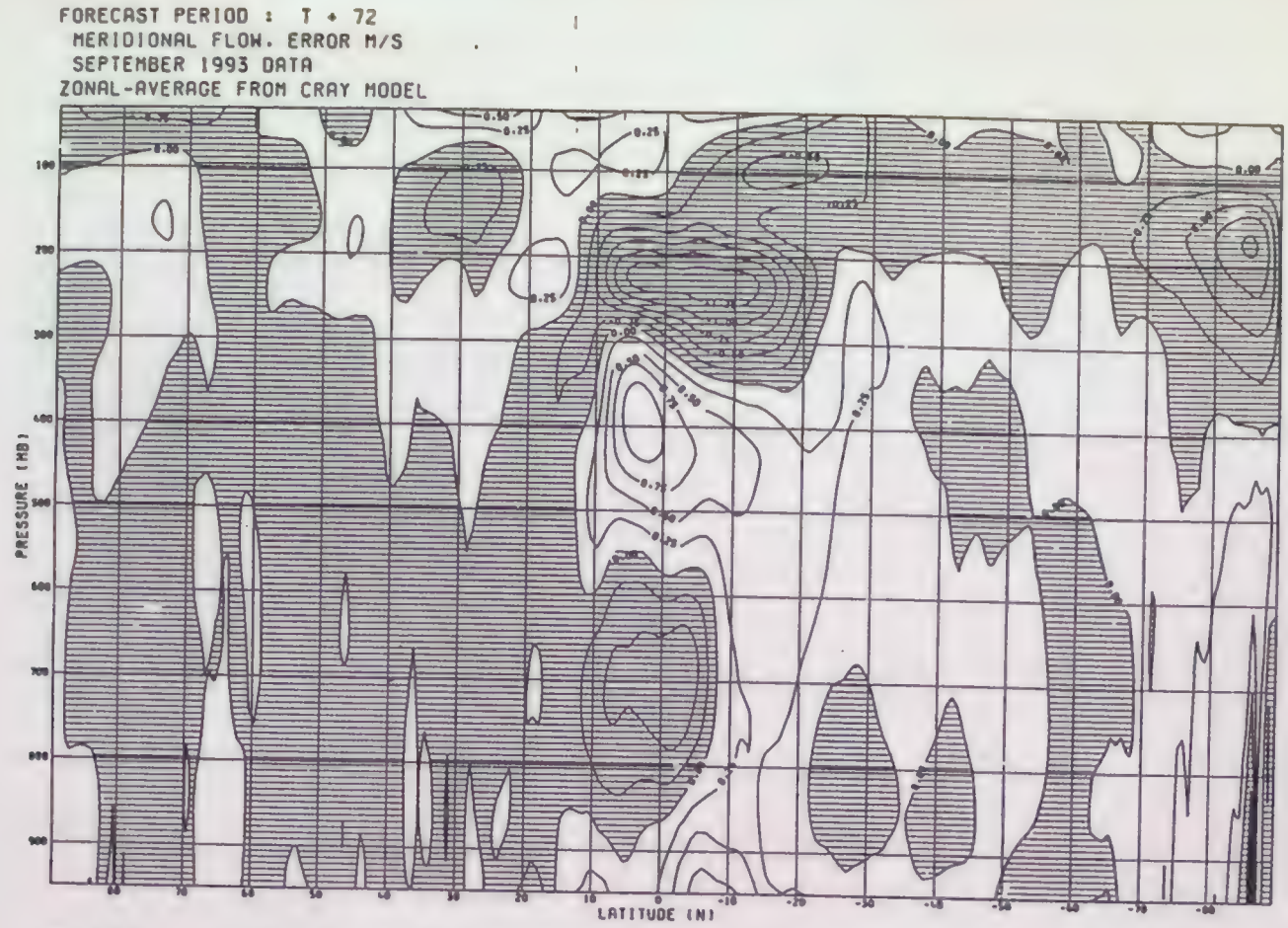
5.17b As Figure 5.17a but for operational forecasts.



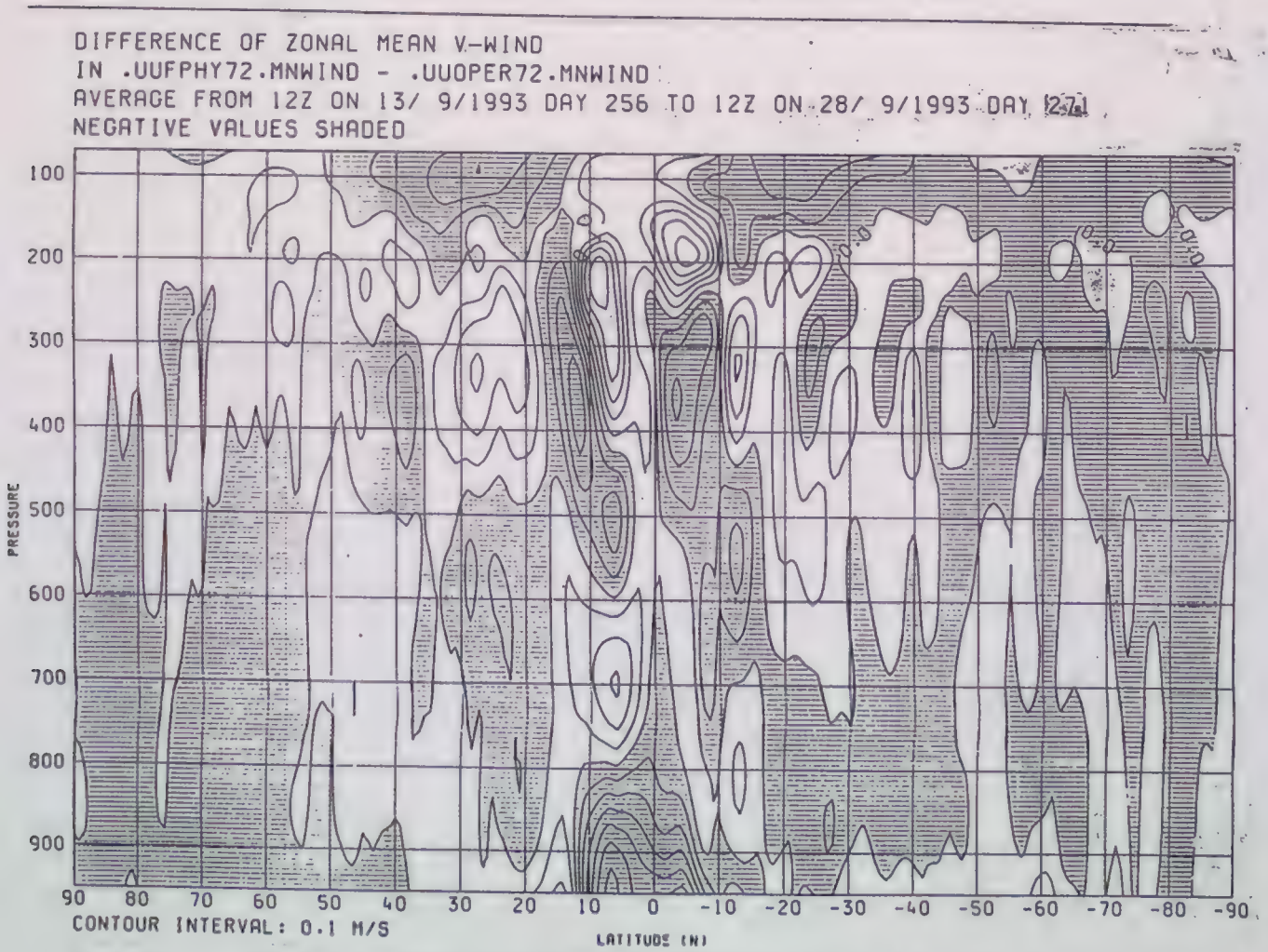


5.18 **Cross section showing zonal mean "v" wind components at 10 standard levels between 950mb and 50mb averaged from operational analyses during the period 12Z 10/09/93 to 12Z 25/09/93.**





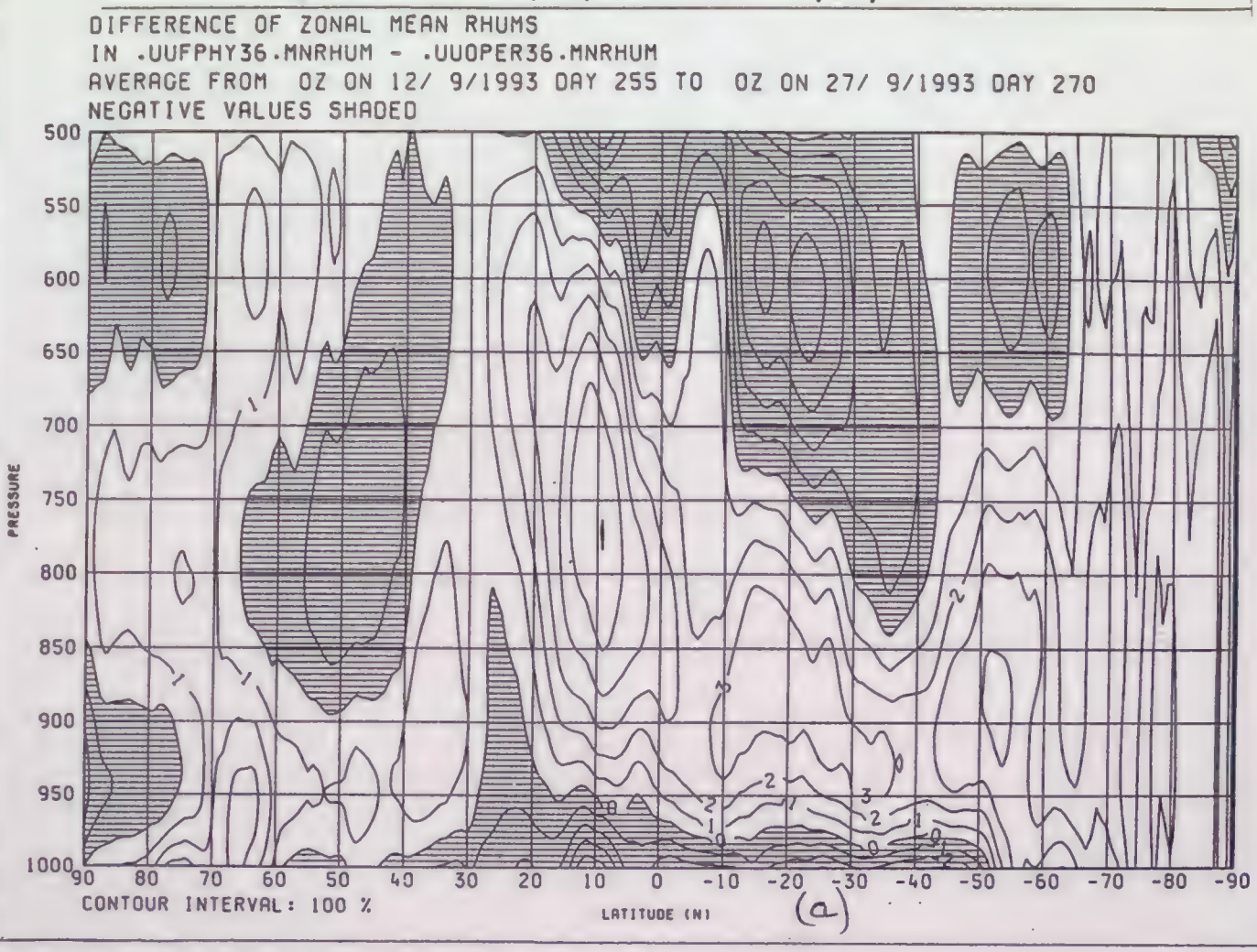
5.19a **Cross section showing zonally averaged meridional flow errors in m/s at T+72 for September 1993.**

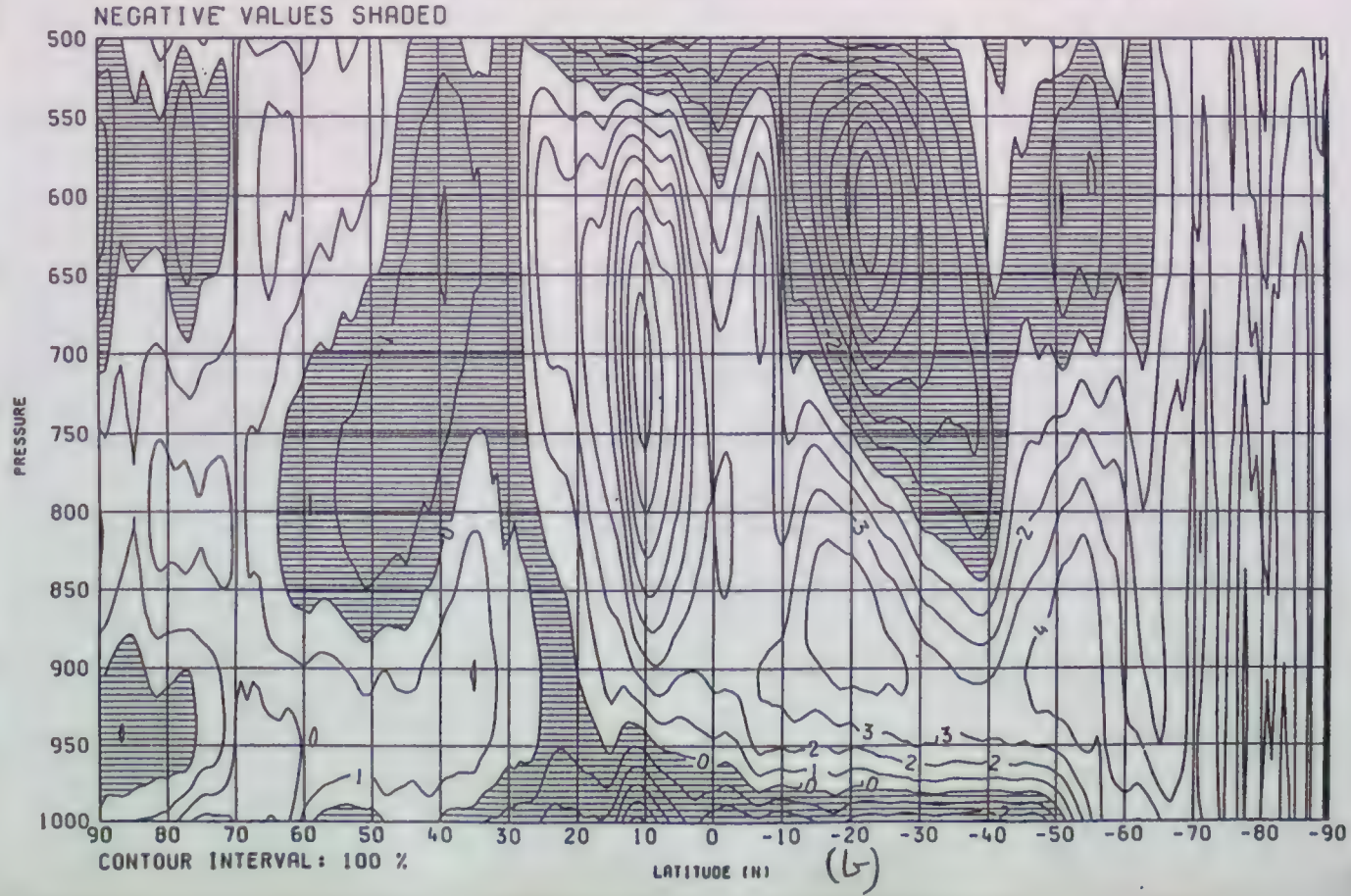


5.19b **Cross section showing differences in the zonal mean "v" wind components at T+72 (trial - operational) averaged over the period 12Z 13/09/93 - 12Z 28/09/93.**

5.20a Cross section showing zonal mean relative humidity differences (trial-operational) from T+36 trial forecasts during the period 00Z 12/09/93 to 00Z 27/09/93.

5.20b As 5.20a but for T+72 forecasts averaged over the period 12Z 13/09/93 to 12Z 28/09/93.

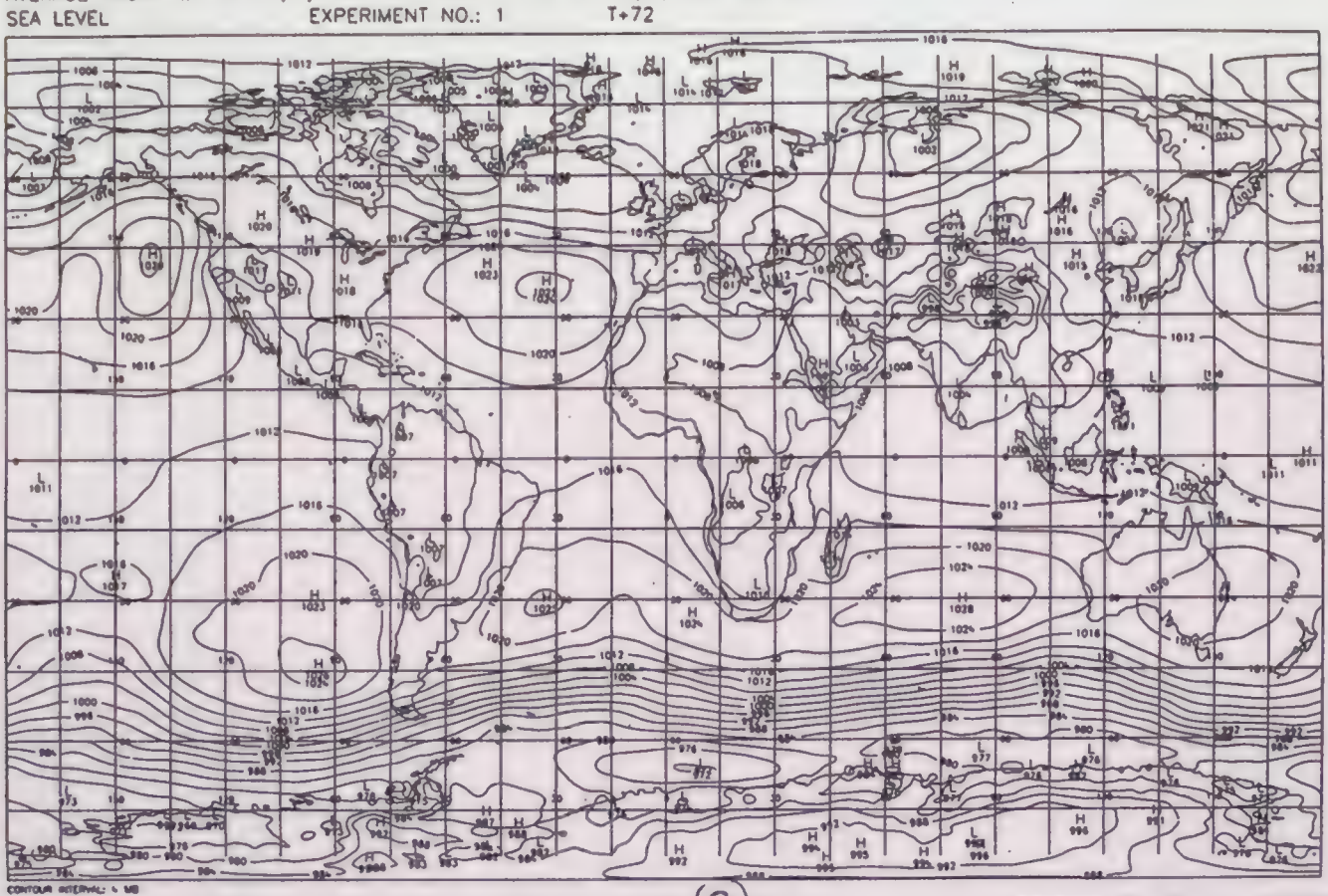




5.21a Mean sea level pressure forecast for T+72 from the trial model meaned over the period 12Z 13/9/93 to 12Z 1/10/93.

5.21b As Figure 5.21a but for the operational model.

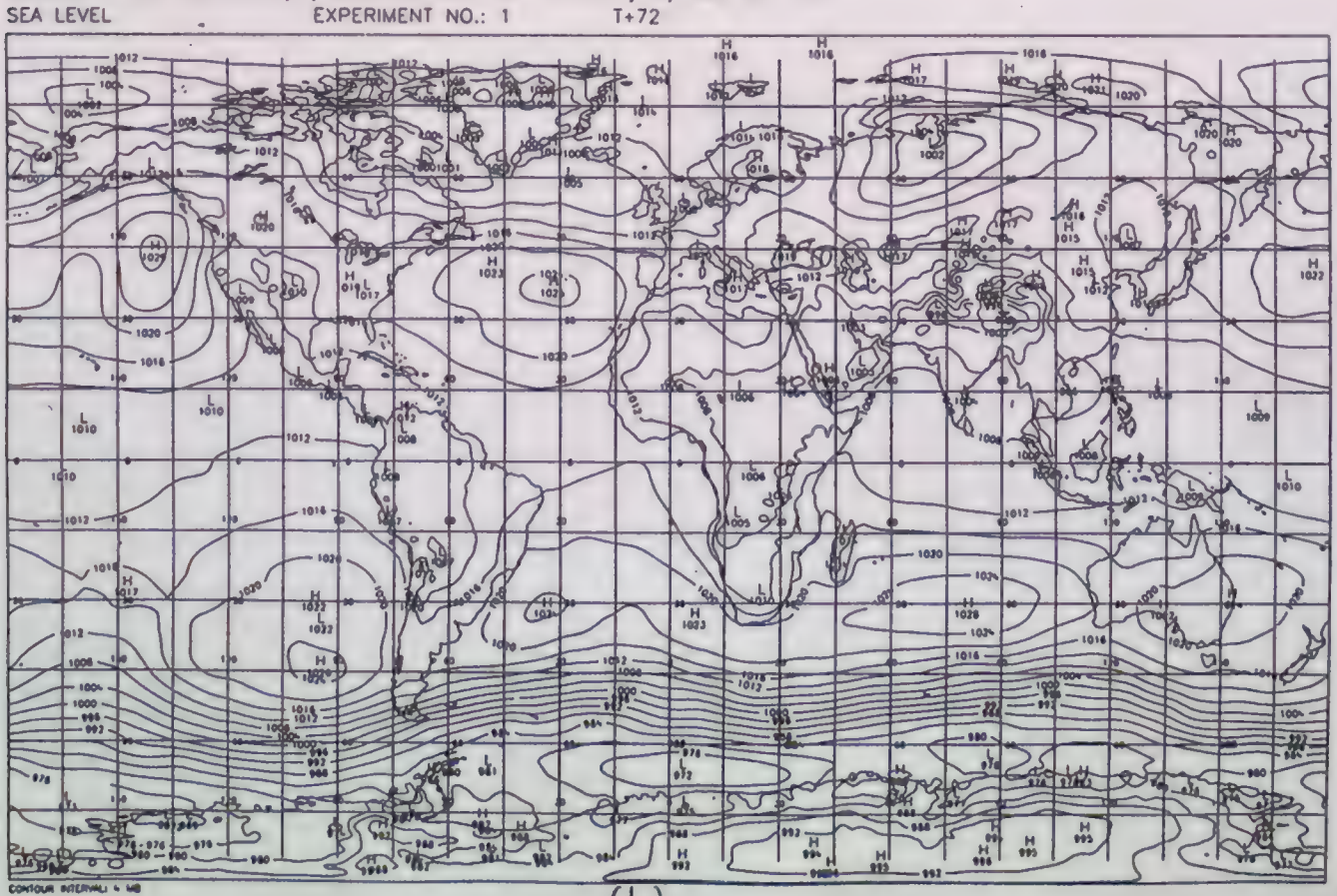
MEAN SEA LEVEL PRESSURE - FROZEN PHYSICS
IN .UUFPHY.MSLP072M
AVERAGE FROM 12Z ON 13/9/1993 DAY 256 TO 12Z ON 30/9/1993 DAY 273
SEA LEVEL EXPERIMENT NO.: 1 T+72



CONTOUR INTERVAL 4 MB

(a)

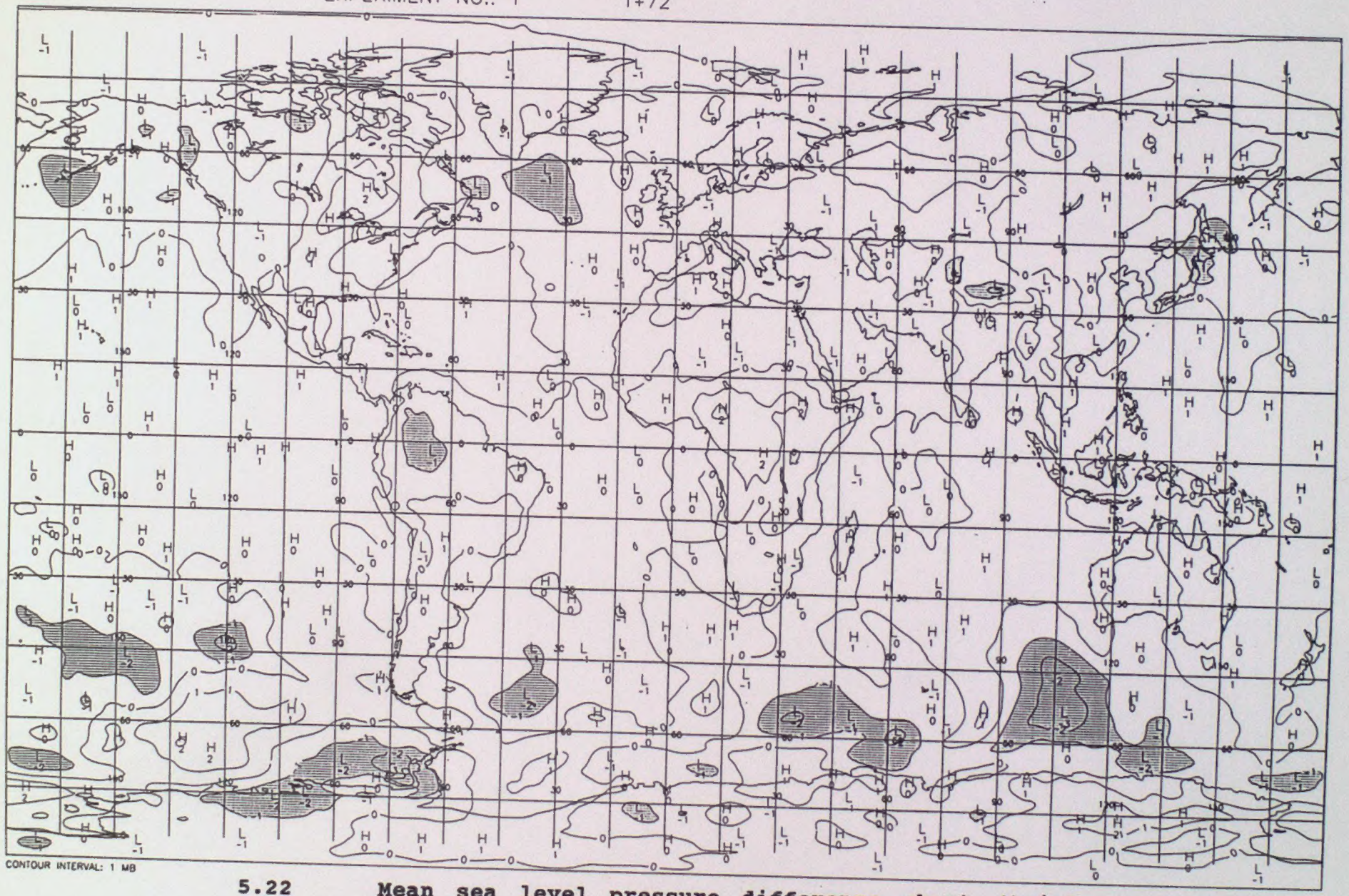
MEAN SEA LEVEL PRESSURE CONTROL VERSION
IN .UUOPER.MSLP072M
AVERAGE FROM 12Z ON 13/9/1993 DAY 256 TO 0Z ON 1/10/1993 DAY 274
SEA LEVEL EXPERIMENT NO.: 1 T+72



CONTOUR INTERVAL 4 MB

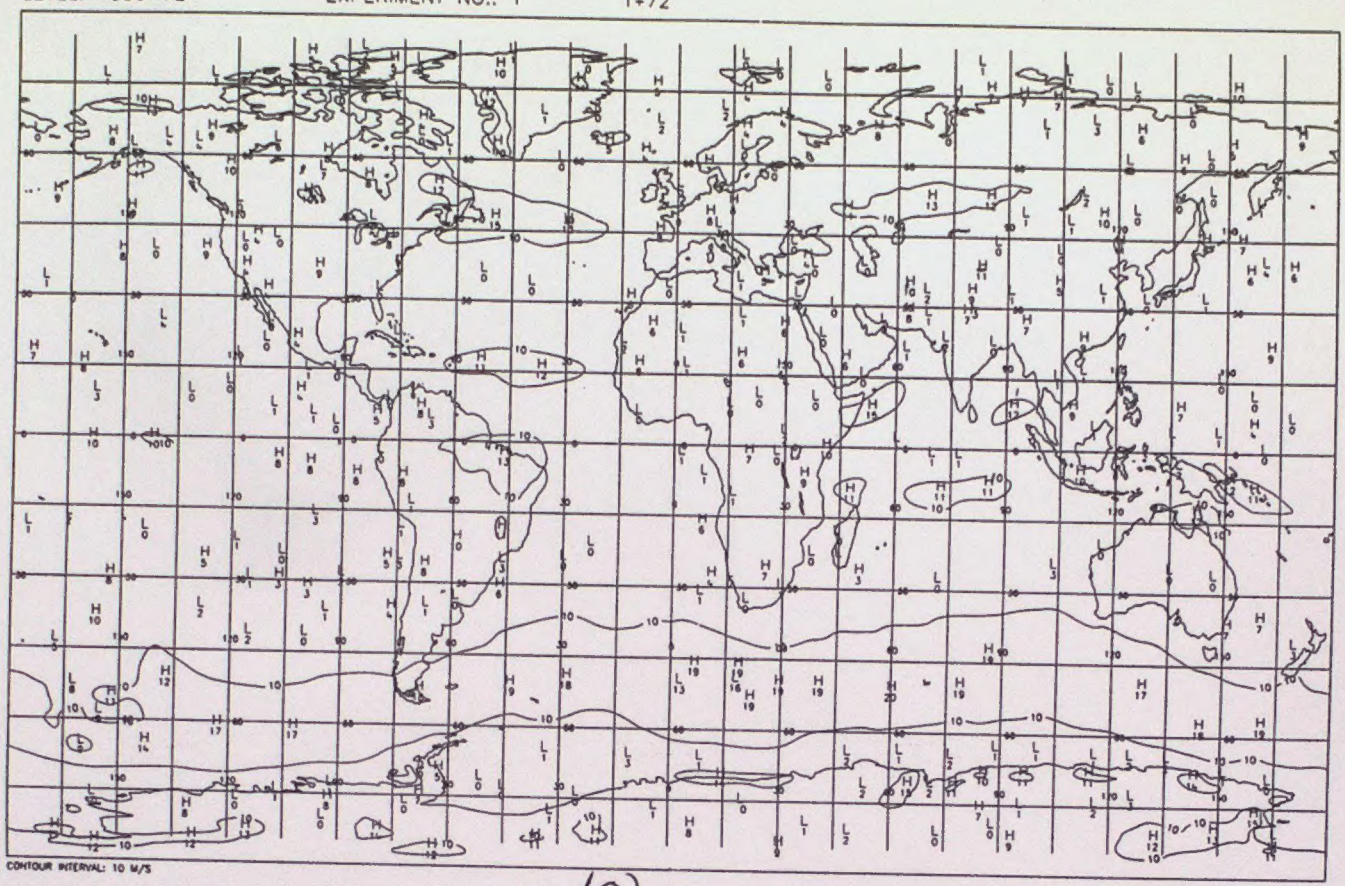
(b)

MEAN SEA LEVEL PRESSURE FPHY-OPER T+072
AVERAGE FROM 12Z ON 13/ 9/1993 DAY 256 TO 12Z ON 30/ 9/1993 DAY 273
SEA LEVEL EXPERIMENT NO.: 1 T+72



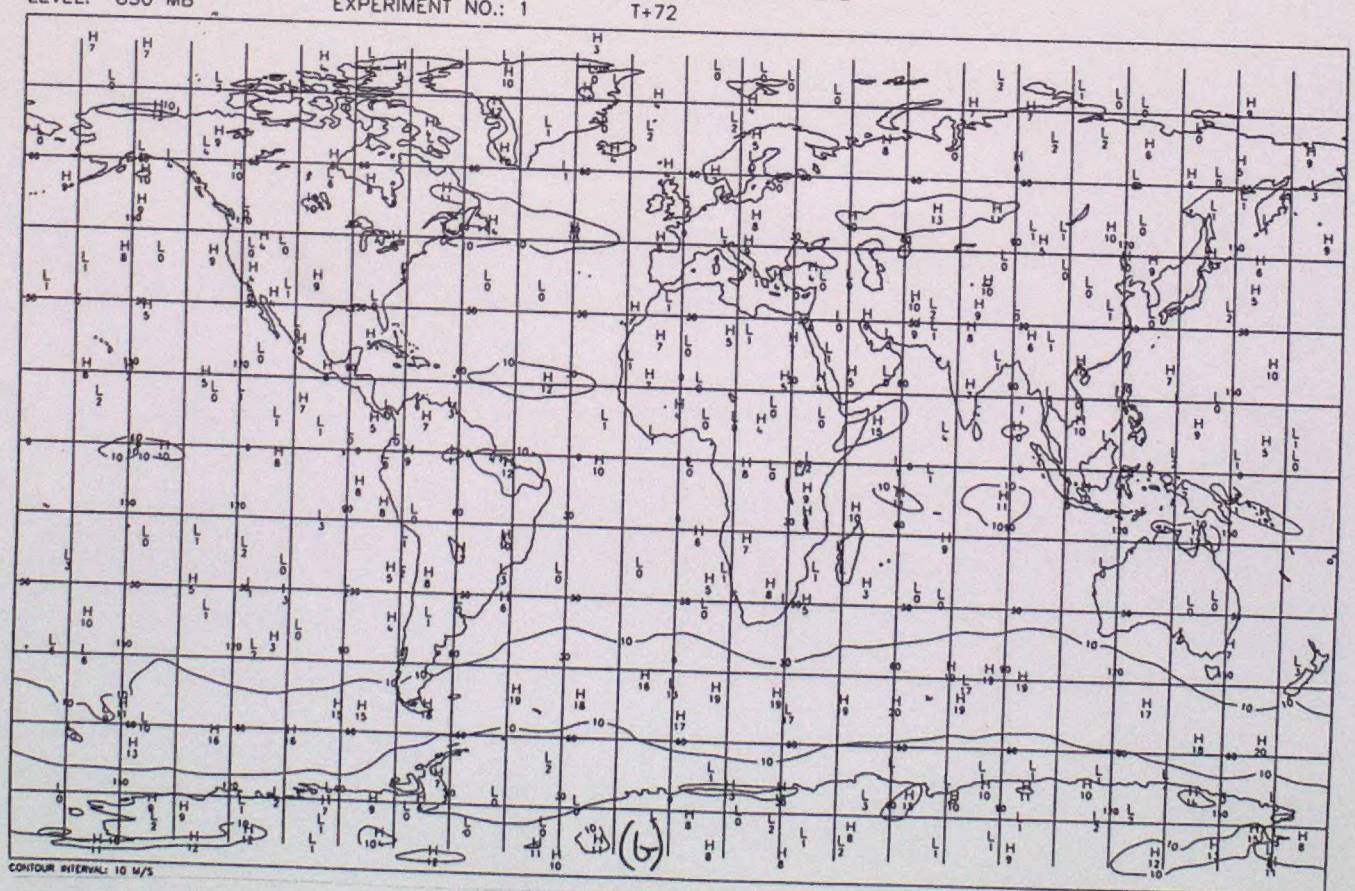
5.22 Mean sea level pressure difference chart (trial - operational) for T+72 meaned over the period 12Z 13/9/93 to 12Z 1/10/93

WINDS -FROZEN PHYSICS PACKAGE
IN .UUFPHY.WIND072M
AVERAGE FROM 12Z ON 13/9/1993 DAY 256 TO 12Z ON 29/9/1993 DAY 272
LEVEL: 850 MB EXPERIMENT NO.: 1 T+72



(a)

WINDS -OPERATIONAL
IN .UUOPER.WIND072M
AVERAGE FROM 12Z ON 13/9/1993 DAY 256 TO 12Z ON 29/9/1993 DAY 272
LEVEL: 850 MB EXPERIMENT NO.: 1 T+72

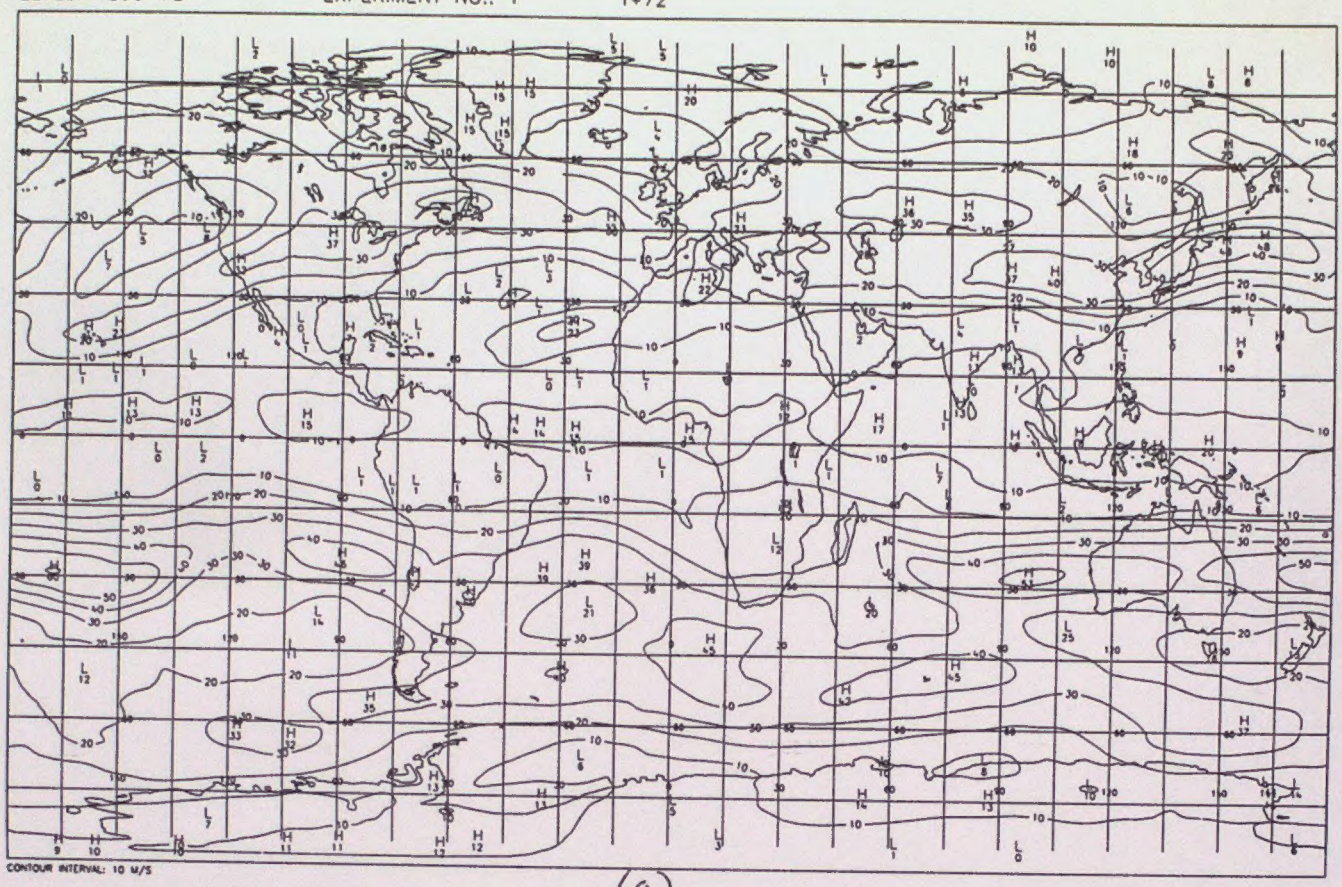


(b)

5.23a **Mean 850mb winds from the trial averaged from T+72 forecasts over the period 12Z 13/09/93 - 29/09/93.**

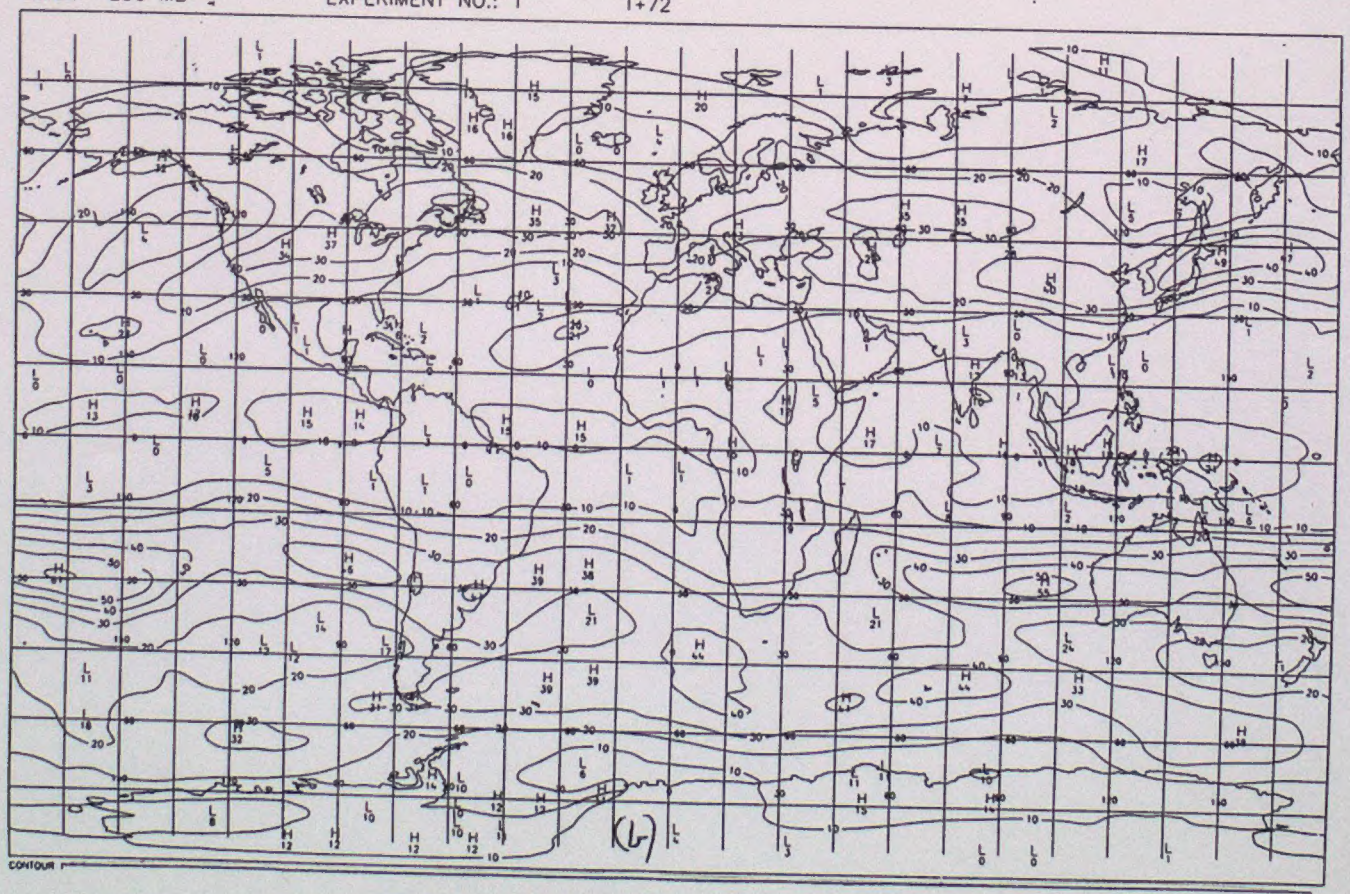
5.23b **As Figure 5.23a but for the operational model.**

WINDS -FROZEN PHYSICS PACKAGE
IN .UUFPHY.WIND072M
AVERAGE FROM 12Z ON 13/9/1993 DAY 256 TO 12Z ON 29/9/1993 DAY 272
LEVEL: 250 MB EXPERIMENT NO.: 1 T+72



(a).

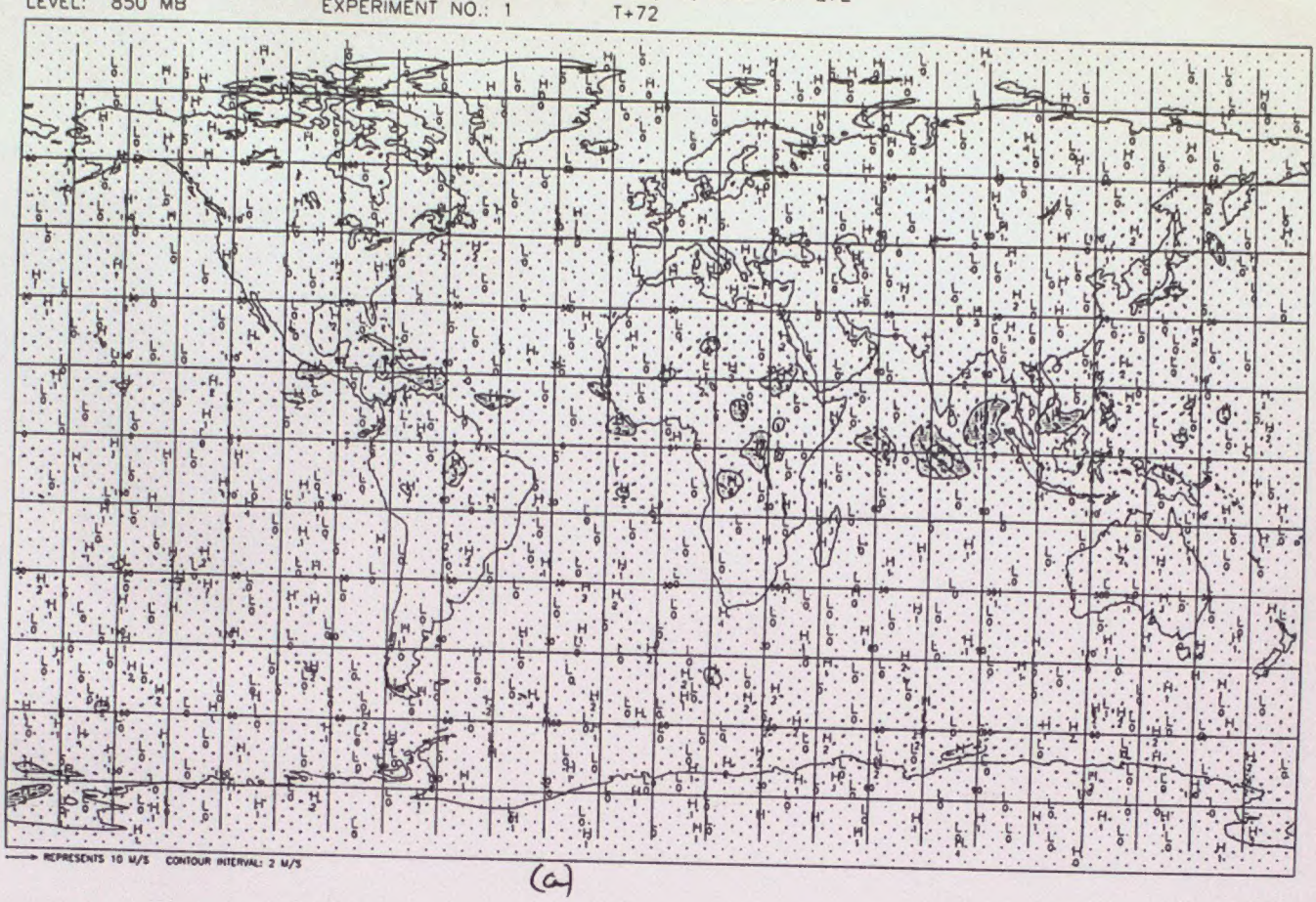
WINDS -OPERATIONAL
IN .UUOPER.WIND072M
AVERAGE FROM 12Z ON 13/9/1993 DAY 256 TO 12Z ON 29/9/1993 DAY 272
LEVEL: 250 MB EXPERIMENT NO.: 1 T+72

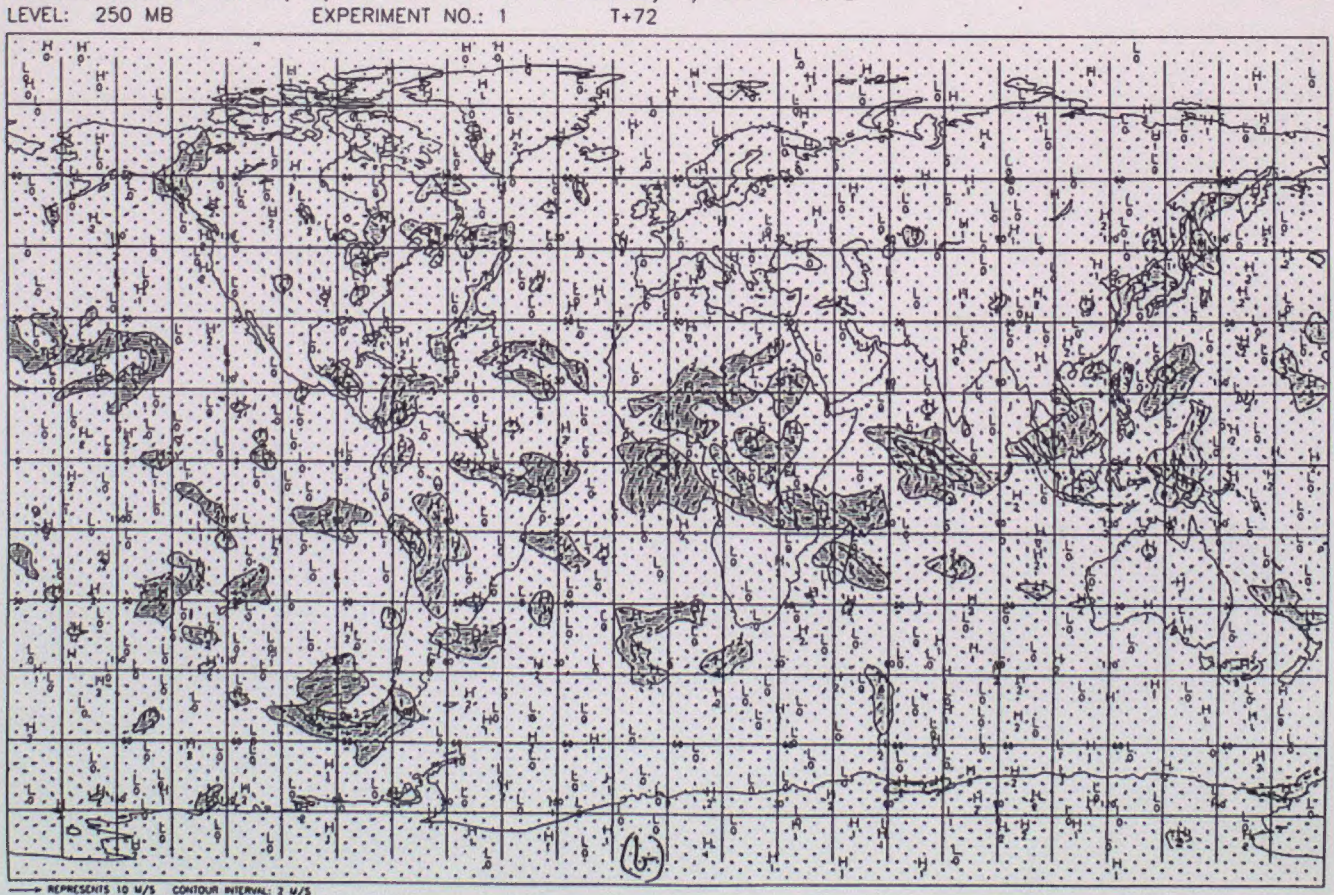


(b)

5.24a **Mean 250mb winds from the trial averaged from T+72 forecasts over the period 12Z 13/09/93 - 29/09/93.**

5.24b **As Figure 5.24a but for the operational model.**





5.25a **Mean 850mb wind difference chart (trial-operational) averaged from T+72 forecasts over the period 12Z 13/09/93 - 29/09/93.**

5.25b **As Figure 5.25a but for 250mb winds.**